

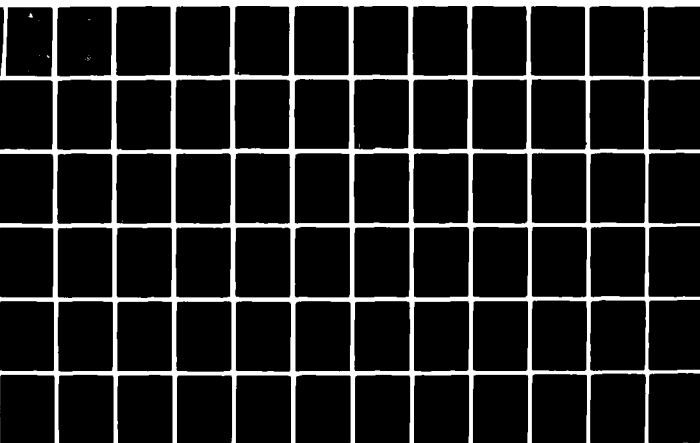
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WEAPONS SYSTEMS RESEARCH LAB ADELAIDE (AUSTRALIA)  
THE USE OF THE 'BLAKE' COMPUTER PROGRAM TO CALCULATE THERMODYNA--ETC(U)  
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WSRL-0269-TR

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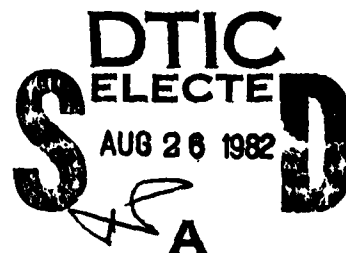
**TECHNICAL REPORT**

**WSRL-0289-TR**

**THE USE OF THE 'BLAKE' COMPUTER PROGRAM TO CALCULATE**  
**THERMODYNAMIC PROPERTIES OF AUSTRALIAN-MADE**  
**GUN PROPELLANTS**

**A.R. RYE**

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DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION

WEAPONS SYSTEMS RESEARCH LABORATORY



TECHNICAL REPORT

WSRL-0269-TR

THE USE OF THE 'BLAKE' COMPUTER PROGRAM TO CALCULATE  
THERMODYNAMIC PROPERTIES OF AUSTRALIAN-MADE GUN PROPELLANTS

A.R. Rye

S U M M A R Y

The BLAKE computer program has been used to calculate certain quantities required for gun interior ballistic simulation and prediction. Thermodynamic data for gun propellants manufactured in Australia, and several which are candidates for local production, are tabulated for reference. A summary of the theoretical framework of the program is included.



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# TABLE OF CONTENTS

	Page
1. INTRODUCTION	1
2. THE THEORETICAL BASIS OF THE PROGRAM	1
2.1 Equation of state considerations	1
2.2 Derivation of virial parameters	1
2.3 Other approaches	2
3. THE STRUCTURE OF THE PROGRAM	3
4. PROGRAM PERFORMANCE	3
4.1 Program accuracy	3
4.2 Program utility	3
5. PROPELLANT FORMULATION DATA	7
5.1 Classification	7
5.2 Data sources	7
5.2.1 Formulation	7
5.2.2 Moisture and solvent levels	7
6. CALCULATED PROPERTIES OF AUSTRALIAN-MADE PROPELLANTS	7
6.1 Data format	8
6.2 Abbreviations	8
7. CONCLUSIONS	9
REFERENCES	10

## LIST OF APPENDICES

I PROPELLANTS OF AUSTRALIAN ORIGIN	13
II PROPELLANTS OF BRITISH ORIGIN	31
III PROPELLANTS OF AMERICAN ORIGIN	51
IV TYPICAL BLAKE OUTPUT	71



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LIST OF TABLES

1. THERMODYNAMIC DATA COMPARISON (SINGLE-BASE - FNH/M1)	4
2. THERMODYNAMIC DATA COMPARISON (DOUBLE-BASE - M26)	5
3. THERMODYNAMIC DATA COMPARISON (DOUBLE-BASE - M9)	5
4. THERMODYNAMIC DATA COMPARISON (TRIPLE-BASE - NQ)	6
5. PROPELLANT INGREDIENT ABBREVIATIONS	8

## 1. INTRODUCTION

Reliable prediction of the performance of gun systems requires detailed knowledge of the chemistry of the propellant combustion gases. Even the most simple models(ref.1,2, and 3) demand information which derives from the thermochemistry of the species formed during burning. The essential problem - for a given propellant formulation and combustion environment - is to predict the types of molecular species formed, and their relative concentrations and energies. Knowledge of these quantities will allow estimates to be made of parameters such as impetus, temperature and covolume which are required by modellers and charge designers. The 'BLAKE' computer program was developed by Dr E. Freedman at the US Army Ballistic Research Laboratory to predict these parameters. This report summarises the theoretical framework of the BLAKE program and tabulates the results of computations performed upon gun propellants manufactured in Australia.

## 2. THE THEORETICAL BASIS OF THE PROGRAM

### 2.1 Equation of state considerations

The temperatures and pressures characteristic of gun propellant combustion preclude the use of an ideal equation of state. Simple or approximate methods often use the Noble-Abel equation:

$$p(V-b) = RT \quad (1)$$

Here  $p$  is the pressure,  $V$  is the gas volume,  $b$  is the covolume,  $R$  is the universal gas constant, and  $T$  is the temperature. This relationship has been used in a number of computation schemes, of which the one described in reference 4 is typical. Although equation (1) is still frequently used in modelling of the gun ballistic cycle, the most commonly used formulation for thermodynamic calculations is the Virial Equation:

$$pV = RT(1 + B(T)/V + C(T)/V^2 + \dots) \quad (2)$$

The virial coefficients  $B(T)$ ,  $C(T)$ , .... are each a function of temperature. Essentially, the second coefficient represents the contribution of two-body collisions to non-ideality; the third and higher-order coefficients represent the perturbations of corresponding multiple-body collisions(ref.5). Corner(ref.6) has shown that the virial coefficients can be calculated using the Lennard-Jones equation to describe the intermolecular potential,  $\Phi(r)$ :

$$\Phi(r) = 4\epsilon[(r/r_0)^{12} - (r/r_0)^6] \quad (3)$$

Here  $\epsilon$  is the depth of the attractive well, and  $r$  is radial distance. The special case,  $r_0$ , is the distance at which the intermolecular attractive and repulsive forces are balanced.

### 2.2 Derivation of virial parameters

BLAKE was developed from the TIGER computer code. TIGER(ref.7) was written by workers at Stanford Research Institute, originally for thermochemical calculations related to explosives. TIGER was an attractive starting point for BLAKE as it did not irretrievably embody any particular equation of state in the source code. TIGER's optional equations are the ideal gas equation and the BKW (Becker-Kistiskowsky-Wilson) equation(ref.8). BLAKE

adds the virial equation to these options. Similar substitutions have been recently made by other workers(ref.9). Freedman(ref.10) describes the specific problems encountered in making the conversion, which are summarised below:

(i) The methodology of Hirschfelder, Curtiss, and Bird (ref.11) is followed to compute the virial co-efficients from the Lennard-Jones intermolecular potential.

(ii) Lennard-Jones parameters are not available for some of the high-temperature species encountered. Where this occurs, the program makes a reasonable guess at the likely value. Freedman's philosophy is that "any guess .... is better than omitting the contribution of these species to the virial co-efficients".

(iii) The computation of virial co-efficients for mixtures is a complicated question, and there is no general consensus as to the best choices of mixing rules. Those chosen for BLAKE are:

$$(r_0)_{ij} = 0.5 [(r_0)_i + (r_0)_j]$$

$$\epsilon_{ij} = [(r_0)_i (r_0)_j]^{1.5} [\epsilon_i \epsilon_j]^{0.5} / (r_0)_{ij}^3$$

$$B(T) = \sum y_i y_j B_{ij}$$

Where  $y_n$  is the mole fraction of the nth species and  $B_{ij}$  is the virial co-efficient computed using  $\epsilon_{ij}$  and  $(r_0)_{ij}$ .

( $\epsilon_{ij}$  and  $(r_0)_{ij}$  refer to  $\epsilon$  and  $r_0$  for interaction between species  $i$  and  $j$  respectively).

The third virial co-efficient  $[C(T)]$  is too important to neglect, but not important enough to justify the inclusion of unavoidably complicated ternary mixing rules. Hirschfelder's hard-sphere values(ref.11) for the third virial co-efficient are provided as a useful approximation.

### 2.3 Other approaches

There is some question as to the most suitable representation of the equation of state. Freedman(ref.10) and Powell(ref.12) have both pointed out conceptual weaknesses in the conjunction of the Virial equation with the Lennard-Jones potential function and suggest alternative approaches. Particular emphasis is placed on choices for the potential function,  $\Phi(r)$ . Nonetheless, at this stage the choices made for BLAKE are appropriate, since -

(a) the primary thermochemical data for propellant gas constituents at high temperatures and pressures are usually available, and

(b) the predicted results are within the limits of current experiment and are consistent with other calculation techniques.

### 3. THE STRUCTURE OF THE PROGRAM

BLAKE is coded in FORTRAN. Several versions are known to exist which are tailored for the FORTRAN peculiarities of different computers. The version operating at DRCS on an IBM 370/3033 mainframe was derived from coding for a UNIVAC 1108. While this version lacks a little of the flexibility of some others, it appears to be the most universally applicable example of the code. It is believed that translation to run on other mainframes would not be especially difficult. There are some non-essential calls to system routines, and IBM FORTRAN peculiarities would need to be modified, but no numerical hazards are expected. This is not necessarily true of other BLAKE versions.

The BLAKE program contains initialising routines which set up the program and make appropriate preparations for gun propellant data input (as distinct from the explosive-orientated input of TIGER). The rest of the program is basically TIGER with suitable changes made, where required, to accommodate the special needs of the gun interior ballistician. These changes are relatively minor. The derivation and output of 'gun' parameters is done at the conclusion of the TIGER-based calculations which dominate the computation.

BLAKE is a fairly amorphous program in the sense that the selection of subroutines used will be determined by the particular task to be performed. The user has considerable control over the types and numbers of the computations performed. A User's Guide(ref.13) will give details of these options. BLAKE is a very complex program; the intending user should consult reference 14 for specific details of the program structure, including flow charts. An outline of the functioning of each of the BLAKE subroutines is included in an appendix to reference 13. The source coding of the program can be made available to intending users, subject to approval by the US. Listings in the form of hardcopy, microfiche, diskette and magnetic tape are available from WSRL.

### 4. PROGRAM PERFORMANCE

#### 4.1 Program accuracy

The BLAKE program has undergone a considerable period of refinement over a period of nearly ten years. Early versions contained coding errors which were significant with some compositions. In a recent report(ref.15), calculations based on Freedman's theoretical approach were shown to be inconsistent with other methods. These results are difficult to reconcile with BLAKE output figures, and may reflect the importance of numerical technique. Certainly, the current version of the BLAKE code produces results which agree well with experiment and other calculation methods. This fact is clearly demonstrated by the figures in Tables 1, 2, 3 and 4 which compare BLAKE calculations for typical single, double and triple-base propellants with theoretical and experimental literature values. The propellants considered are FNH/M1 (Table 1), M26 (Table 2), M9 (Table 3) and NQ (Table 4). The comparison figures are from Volk(ref.5), Baer and Bryson(ref.16), Hunt(ref.17), Jahnk(ref.18), and Picard(ref.19).

#### 4.2 Program utility

BLAKE has the technical capability to perform calculations on mixtures containing up to thirty gaseous species and ten condensed species. In practice(ref.20), limitations imposed by convergence difficulties and run-time restraints limit this capability to about twenty gaseous species and four condensed species. The compositions tabulated in the appendices to this report, and similar formulations, will seldom encounter such problems.



TABLE 1. THERMODYNAMIC DATA COMPARISON (SINGLE-BASE - FNH/M1)

Data Source <sup>1</sup>	Flame Temp. (°K)	Impetus (j/g)	Gamma	Covolume (cm <sup>3</sup> /g)	Mean Mol. Weight	Total Gas Output (moles/kg)
BLAKE	2440	917	1.267	1.11	22.13	45.19
BAER/ BRYSON	2433	914	1.264	1.12	22.19	45.06
HUNT <sup>2</sup>	2510	943	1.280	0.97		
JAHNK (Theory) (Exptl.)		912 900-918		1.14 1.05		
PICARD <sup>3</sup>	2461 ±48	918 ±18	1.258 ±0.01	1.05 ±0.05	22.33	44.78 ±0.2

## Notes:

1. These data are calculated for propellants of the FNH/M1 formulation at loading densities of 0.2 g/cm<sup>3</sup>.
2. Drummond(ref.21) has shown that the use of inaccurate thermochemical data is the major factor leading to the inconsistency of these figures with modern calculations, but erroneously assigns his reference to Corner(ref.6) rather than Hunt(ref.17).
3. These figures are the means of calculations performed on the same nominal composition by six NATO countries. The ranges quoted are standard deviations. Various calculation procedures were employed.

TABLE 2. THERMODYNAMIC DATA COMPARISON (DOUBLE-BASE - M26)

Data Source	Flame Temp. (°K)	Impetus (j/g)	Gamma	Covolume (cm <sup>3</sup> /g)	Mean Mol. Weight	Total Gas Output (moles/kg)
BLAKE	3097	1070	1.237	1.030	23.96	41.55
BAER/ BRYSON	3092	1081	1.238		23.76	42.09
VOLK	3050	1065				
PICARD	3132	1085	1.238	1.038	24.01	41.64

Note: These data are calculated for propellants of the M26 formulation at loading densities of 0.2 g/cm<sup>3</sup>.

TABLE 3. THERMODYNAMIC DATA COMPARISON (DOUBLE-BASE - M9)

Data Source	Flame Temp. (°K)	Impetus (j/g)	Gamma	Covolume (cm <sup>3</sup> /g)	Mean Mol. Weight	Total Gas Output (moles/kg)
BLAKE	3834	1164	1.205	0.940	27.38	36.52
BAER/ BRYSON	3840	1186	1.207	1.107	26.45	37.80
JAHNK (Theory) (Exptl.)		1158 1095		0.95 1.01		
PICARD	3858 3802	1188 1143	1.204 1.210	1.019 0.938	26.95 27.67	37.10 36.14

Note: These data are calculated for propellants of the M9 formulation at loading densities of 0.2 g/cm<sup>3</sup>.

TABLE 4. THERMODYNAMIC DATA COMPARISON (TRIPLE-BASE - NQ)

Data Source <sup>1</sup>	Flame Temp. (°K)	Impetus (j/g)	Gamma	Covolume (cm <sup>3</sup> /g)	Mean Mol. Weight	Total Gas Output (moles/kg)
BLAKE	2766	1027	1.249	1.08	22.37	44.70
BAER/ BRYSON <sup>2</sup>	2571	984	1.257		21.76	45.95
HUNT <sup>3</sup>	2800	1060	1.250	0.98		
PICARD	2834	1051	1.259	0.95	22.47	44.45

## Notes:

1. These data are calculated for propellants of the NQ formulation at loading densities of 0.2 g/cm<sup>3</sup>.
2. These figures relate to the American propellant T34, which is very similar in formulation to NQ.
3. See footnote 2 to Table 1.

Occasionally, unusual mixtures will entail the formation of sufficient quantities of condensed phases to cause difficulties. Special techniques are available to handle this eventuality which are documented in reference 13.

## 5. PROPELLANT FORMULATION DATA

### 5.1 Classification

The propellants considered in this study are either available from the Australian service inventory or are candidates for inclusion. They fall into three broad classes:

- (a) propellants of Australian origin
- (b) propellants of British origin
- (c) propellants of American origin These classifications are basically for convenience - considerable overlap, even duplication, exists within these groups. Although some of the propellants in group (a) are derived from propellants of overseas origin, they have undergone extensive local development and are considered uniquely Australian.

BLAKE calculations for these three classes of propellant are included in the appendices to this report.

### 5.2 Data sources

#### 5.2.1 Formulation

The majority of the formulation data comes from Baer and Bryson(ref.16), Hunt(ref.17), Picard(ref.19), the AMCP Pamphlet 706-150(ref.22), Wilkie(ref.23), and MIL-STD-652(ref.24). It should be recognised that these figures represent the nominal formulae only; most production propellants will vary slightly. Methods for the determination of nitrogen in nitrocellulose vary from country to country. Although undoubted minor discrepancies are introduced by this factor, specified nitrogen levels have been accepted at face value.

#### 5.2.2 Moisture and solvent levels

The calculated ballistic parameters of military gun propellants are quite sensitive to the levels of moisture and residual solvent entrained in the propellant grain. This phenomenon has been extensively studied. Baer and Bryson's results(ref.16) are typical. In general, moisture and solvent levels in the formulations considered in this report are based on analytical data or are drawn from the graphs in reference 24. Ethanol has been chosen as the principal residual solvent in propellants subjected to ether/ethanol processing. This may not always be true. However, at the solvent levels found in gun propellants, ether and alcohol have very similar effects on the results.

## 6. CALCULATED PROPERTIES OF AUSTRALIAN-MADE PROPELLANTS

The appendices to this report contain extracts of BLAKE output. Appendix I includes data for Australian propellants, while Appendices II and III treat propellants of British and American origin respectively.

Appendix IV is a reproduction of a typical BLAKE computer output.

## 6.1 Data format

In the appendices, information relating to each propellant is presented in three sections. The first section contains details of the formulation, including the elemental composition of each ingredient and its heat of formation. The second section summarises the interior ballistic parameters of the propellant in tabular form, using both traditional and SI units. Finally, predicted combustion products and their relative abundances are presented. The parameter 'DELTA Q' tabulated in this segment refers to the constant-volume heat of explosion. The last two sections include calculations spanning the range of gas loading densities from 0.1 to 0.3 g/cm<sup>3</sup>. Calculations for deterred (moderated) propellants relate to the overall composition.

## 6.2 Abbreviations

Abbreviations are used to describe the ingredients in a propellant formulation. Data for most standard materials are embedded in the program. Unusual ingredients are specified by the user as required. Typical abbreviations are listed in Table 5.

TABLE 5. PROPELLANT INGREDIENT ABBREVIATIONS

ABBREVIATION	CHEMICAL NAME
NC1	Nitrocellulose - 12.00% Nitrogen
NC2	Nitrocellulose - 12.30% Nitrogen
NC3	Nitrocellulose - 12.60% Nitrogen
NC4	Nitrocellulose - 13.00% Nitrogen
NC5	Nitrocellulose - 13.15% Nitrogen
NC6	Nitrocellulose - 13.25% Nitrogen
NG	Nitroglycerin
NQ	Nitroguanidine
DP	Diphenylamine
EC	Ethyl centralite (Carbamite)
RES	Resorcinol
AL	Ethyl alcohol
AC	Acetone
H2O	Water
C	Carbon (graphite)
KS	Potassium sulphate
KN	Potassium nitrate
CRY	Cryolite (sodium aluminium fluoride)
PBC	Lead carbonate
DN	Dinitrotoluene
DB	Dibutylphthalate
DOP	Diethylphthalate
NBUS	n-Butyl stearate
RDX	Cyclotrimethylene trinitramine
HMX	Cyclotetramethylene tetranitramine
TAGN	Triaminoguanidine nitrate

## 7. CONCLUSIONS

The version of BLAKE installed on the IBM 370/3033 at DRCS is capable of reliably predicting thermodynamic parameters associated with gun propellants. These data have been systematically collated for gun propellants manufactured in Australia. In addition, the program can be used, for any given formulation, to indicate accurately the expected relative change in propellant performance resulting from alteration to its composition.

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APPENDIX I

PROPELLANTS OF AUSTRALIAN ORIGIN

This appendix presents calculated thermodynamic data for the following propellant formulations:

AR2201	7.62 mm rifle (ball and tracer)
AR2203	20 mm Hispano-Suiza cannon
AR2204	7.62 mm rifle (barrel proof)
AR2205	7.62 mm rifle (grenade launcher)
AR2206	7.62 mm rifle (ball and tracer)
AR4001	7.62 mm rifle (blank cartridge)
AR4002	9 mm ball cartridge
AR5401	30 mm DEFA cannon

(See page 7 for table of ingredient abbreviations)

## \*\*\* PROPELLANT AR2201 \*\*\*

## INGREDIENT AND FORMULATION INFORMATION

NAME	WT %	MOLE %	$\Delta H$ (CAL/MOL)	EMPIRICAL FORMULA
NC5	91.010	0.273	$-0.1646 \times 10^9$	C H O N 6000 7364 10271 2636
DP	0.890	4.435	$0.3107 \times 10^5$	C H N 12 11
KS	0.790	3.823	$-0.3427 \times 10^6$	K SO 2 4
C	0.200	14.055	0.0	C
DN	5.920	27.410	$-0.1710 \times 10^5$	C H O N 7 6 4 2
H2O	0.990	46.342	$-0.6832 \times 10^5$	H O 2
AL	0.200	3.661	$-0.6642 \times 10^5$	C H O 2 6

ENERGY OF FORMATION: -2483.9 JOULES/GRAM

## ELEMENTAL COMPOSITION (MOLE %)

C	23.769
H	29.183
O	37.183
N	9.722
K	0.095
S	0.048

## \* \* SUMMARY OF PROPELLANT GAS THERMODYNAMIC PROPERTIES \* \*

	L.D. G/CM <sup>3</sup>	TEMP K	PRESSURE MPA	IMPETUS J/G	MOL WT	CO-VOL CM <sup>3</sup> /G	I.B. GAMMA	CP J/MOL
1)	0.10	2940.	112.93	1008.00	24.24	1.073	1.2368	43.90
2)	0.20	2948.	254.31	1009.73	24.27	1.029	1.2400	44.32
3)	0.30	2953.	429.67	1010.64	24.29	0.981	1.2457	44.83

	L.D. G/CM <sup>3</sup>	TEMP K	PRESSURE PSIA	IMPETUS FT-LB/LB	MOL WT	CO-VOL IN <sup>3</sup> /LB	I.B. GAMMA	CP CAL/MOL
1)	0.10	2940.	16378.7	337281.4	24.24	29.687	1.2368	10.493
2)	0.20	2948.	36884.7	337861.9	24.27	28.480	1.2400	10.593
3)	0.30	2953.	62318.4	338169.4	24.29	27.149	1.2457	10.714

## \*\*\* PROPELLANT AR2201 \*\*\*

PREDICTED COMBUSTION PRODUCTS  
CONSTITUENT CONCENTRATIONS - MOLES PER KG OF PROPELLANT

NAME		1)	2)	3)
CO	GAS	18.4173	18.4517	18.4670
H2O	GAS	8.53043	8.59086	8.63275
H2	GAS	5.27670	5.21119	5.14917
N2	GAS	4.61847	4.61256	4.60350
CO2	GAS	4.17178	4.12304	4.09166
KOH	GAS	$2.22119 \times 10^{-2}$	$3.01632 \times 10^{-2}$	$3.60912 \times 10^{-2}$
COS	GAS	$1.59524 \times 10^{-2}$	$2.29586 \times 10^{-2}$	$2.79639 \times 10^{-2}$
NH3	GAS	$5.51418 \times 10^{-3}$	$1.34949 \times 10^{-2}$	$2.48024 \times 10^{-2}$
NO	GAS	$2.74349 \times 10^{-3}$	$1.82743 \times 10^{-3}$	$1.38579 \times 10^{-3}$
HCN	GAS	$2.95478 \times 10^{-3}$	$7.69178 \times 10^{-3}$	$1.51288 \times 10^{-2}$
O2	GAS	$1.25068 \times 10^{-4}$	$5.29196 \times 10^{-5}$	$2.92131 \times 10^{-5}$
CH4	GAS	$1.58003 \times 10^{-4}$	$8.48919 \times 10^{-4}$	$2.60532 \times 10^{-3}$
K	GAS	$6.84407 \times 10^{-2}$	$6.04910 \times 10^{-2}$	$5.45664 \times 10^{-2}$
HNO	GAS	$1.61641 \times 10^{-5}$	$1.72503 \times 10^{-5}$	$1.81377 \times 10^{-5}$
S	GAS	$1.30701 \times 10^{-3}$	$7.46934 \times 10^{-4}$	$4.74147 \times 10^{-4}$
OH	GAS	$2.80251 \times 10^{-2}$	$1.84384 \times 10^{-2}$	$1.38414 \times 10^{-2}$
KO	GAS	$2.09171 \times 10^{-5}$	$1.91794 \times 10^{-5}$	$1.77044 \times 10^{-5}$
SO	GAS	$7.99641 \times 10^{-3}$	$4.56868 \times 10^{-3}$	$2.89528 \times 10^{-3}$
HS	GAS	$1.80219 \times 10^{-2}$	$1.55203 \times 10^{-2}$	$1.29195 \times 10^{-2}$
CH3	GAS	$4.02091 \times 10^{-5}$	$1.55460 \times 10^{-4}$	$3.93319 \times 10^{-4}$
H	GAS	$5.58131 \times 10^{-2}$	$3.63887 \times 10^{-2}$	$2.71924 \times 10^{-2}$
O	GAS	$1.89523 \times 10^{-4}$	$8.34706 \times 10^{-5}$	$4.80630 \times 10^{-5}$
CHO	GAS	$2.61855 \times 10^{-3}$	$4.40571 \times 10^{-3}$	$6.42110 \times 10^{-3}$
KSO4	GAS	$9.49783 \times 10^{-10}$	$2.38601 \times 10^{-9}$	$3.90569 \times 10^{-9}$
CN	GAS	$4.19365 \times 10^{-6}$	$7.52821 \times 10^{-6}$	$1.16679 \times 10^{-5}$
S2	GAS	$1.02928 \times 10^{-3}$	$7.70925 \times 10^{-4}$	$5.42300 \times 10^{-4}$
SO3	GAS	$5.83084 \times 10^{-7}$	$3.39097 \times 10^{-7}$	$2.16798 \times 10^{-7}$
C(S)	SOLID	0.0	0.0	0.0
KSO\$	SOLID	0.0	0.0	0.0
KSO\$	LIQUID	0.0	0.0	0.0
TOTAL GAS (MOLES/KG)		41.2479	41.2080	41.1714
DELTA Q (J/G)		-3243.0	-3247.3	-3249.7

## \*\*\* PROPELLANT AR2203 (TIN OMITTED) \*\*\*

## INGREDIENT AND FORMULATION INFORMATION

NAME	WT %	MOLE %	$\Delta H$ (CAL/MOL)	EMPIRICAL FORMULA
NC5	93.020	0.330	$-0.1646 \times 10^9$	C H O N 6000 7364 10271 2636
DP	0.900	5.304	$0.3107 \times 10^5$	C H N 12 11
KS	0.800	4.578	$-0.3427 \times 10^6$	K SO 2 4
C	0.100	8.310	0.0	C
DN	3.980	21.792	$-0.1710 \times 10^5$	C H O N 7 6 4 2
H2O	1.000	55.356	$-0.6832 \times 10^5$	H O 2
AL	0.200	4.329	$-0.6642 \times 10^5$	C H O 2 6

ENERGY OF FORMATION: -2527.9 JOULES/GRAM

## ELEMENTAL COMPOSITION (MOLE %)

C	23.404
H	29.143
O	37.592
N	9.716
K	0.097
S	0.048

## \* \* SUMMARY OF PROPELLANT GAS THERMODYNAMIC PROPERTIES \* \*

	L.D. G/CM <sup>3</sup>	TEMP K	PRESSURE MPA	IMPETUS J/G	MOL WT	CO-VOL CM <sup>3</sup> /G	I.B. GAMMA	CP J/MOL
1)	0.10	3000	113.90	1017.90	24.50	1.061	1.2334	44.43
2)	0.20	3010	256.25	1019.99	24.53	1.019	1.2364	44.85
3)	0.30	3015	432.51	1021.12	24.55	0.972	1.2420	45.35
	L.D. G/CM <sup>3</sup>	TEMP K	PRESSURE PSIA	IMPETUS FT-LB/LB	MOL WT	CO-VOL IN <sup>3</sup> /LB	I.B. GAMMA	CP CAL/MOL
1)	0.10	3000	16519.4	340598.7	24.504	29.381	1.2334	10.620
2)	0.20	3010	37166.3	341295.4	24.528	28.204	1.2364	10.720
3)	0.30	3015	62730.5	341673.8	24.549	26.906	1.2420	10.840

## \*\*\* PROPELLANT AR2203 (TIN OMITTED) \*\*\*

PREDICTED COMBUSTION PRODUCTS  
CONSTITUENT CONCENTRATIONS - MOLES PER KG OF PROPELLANT

NAME		1)	2)	3)
CO	GAS	17.7100	17.7462	17.7659
H2O	GAS	8.90539	8.96964	9.01414
H2	GAS	4.84559	4.78170	4.72308
N2	GAS	4.60650	4.60193	4.59455
CO2	GAS	4.48888	4.43966	4.40574
KOH	GAS	$2.43364 \times 10^{-2}$	$3.27487 \times 10^{-2}$	$3.89137 \times 10^{-2}$
COS	GAS	$1.41344 \times 10^{-2}$	$2.11164 \times 10^{-2}$	$2.63295 \times 10^{-2}$
NH3	GAS	$4.72062 \times 10^{-3}$	$1.15037 \times 10^{-2}$	$2.10701 \times 10^{-2}$
NO	GAS	$4.09950 \times 10^{-3}$	$2.75010 \times 10^{-3}$	$2.09402 \times 10^{-3}$
HCN	GAS	$2.43550 \times 10^{-3}$	$6.31002 \times 10^{-3}$	$1.23518 \times 10^{-2}$
O2	GAS	$2.41778 \times 10^{-4}$	$1.03476 \times 10^{-4}$	$5.75076 \times 10^{-5}$
CH4	GAS	$9.75907 \times 10^{-5}$	$5.19482 \times 10^{-4}$	$1.58277 \times 10^{-3}$
K	GAS	$6.74533 \times 10^{-2}$	$5.90449 \times 10^{-2}$	$5.28840 \times 10^{-2}$
HNO	GAS	$2.34757 \times 10^{-5}$	$2.51824 \times 10^{-5}$	$2.65369 \times 10^{-5}$
S	GAS	$1.51534 \times 10^{-3}$	$9.04794 \times 10^{-4}$	$5.90750 \times 10^{-4}$
OH	GAS	$3.84531 \times 10^{-2}$	$2.54383 \times 10^{-2}$	$1.91555 \times 10^{-2}$
KO	GAS	$3.03600 \times 10^{-5}$	$2.77197 \times 10^{-5}$	$2.54716 \times 10^{-5}$
SO	GAS	$1.03236 \times 10^{-2}$	$6.17031 \times 10^{-3}$	$4.02623 \times 10^{-3}$
HS	GAS	$1.79810 \times 10^{-2}$	$1.61315 \times 10^{-2}$	$1.37880 \times 10^{-2}$
CH3	GAS	$3.08155 \times 10^{-5}$	$1.18391 \times 10^{-4}$	$2.97714 \times 10^{-4}$
H	GAS	$6.40929 \times 10^{-2}$	$4.19207 \times 10^{-2}$	$3.13782 \times 10^{-2}$
O	GAS	$3.22786 \times 10^{-4}$	$1.43505 \times 10^{-4}$	$8.30587 \times 10^{-5}$
CHO	GAS	$2.76362 \times 10^{-3}$	$4.64714 \times 10^{-3}$	$6.75870 \times 10^{-3}$
KSO4	GAS	$1.37858 \times 10^{-9}$	$3.54506 \times 10^{-9}$	$5.88309 \times 10^{-9}$
CN	GAS	$4.56477 \times 10^{-6}$	$8.19229 \times 10^{-6}$	$1.26626 \times 10^{-5}$
S2	GAS	$9.77350 \times 10^{-4}$	$7.93513 \times 10^{-4}$	$5.88340 \times 10^{-4}$
SO3	GAS	$1.07136 \times 10^{-6}$	$6.54795 \times 10^{-7}$	$4.32310 \times 10^{-7}$
C(S)	SOLID	0.0	0.0	0.0
KSO\$	SOLID	0.0	0.0	0.0
KSO\$	LIQUID	0.0	0.0	0.0
TOTAL GAS (MOLES/KG)		40.8104	40.7695	40.7354
DELTA Q (J/G)		-3333.8	-3339.8	-3342.5

## \*\*\* PROPELLANT AR2204 \*\*\*

## INGREDIENT AND FORMULATION INFORMATION

NAME	WT %	MOLE %	$\Delta H$ (CAL/MOL)	EMPIRICAL FORMULA
NC5	96.030	0.408	$-0.1646 \times 10^9$	C H O N 6000 7364 10271 2636
DP	0.890	6.279	$0.3107 \times 10^5$	C H N 12 11
KS	0.790	5.413	$-0.3427 \times 10^6$	K SO 2 4
C	0.100	9.950	0.0	C
DN	0.990	6.490	$-0.1710 \times 10^5$	C H O N 7 6 4 2
H2O	1.000	66.276	$-0.6832 \times 10^5$	H O 2
AL	0.200	5.183	$-0.6642 \times 10^5$	C H O 2 6

ENERGY OF FORMATION: -2589.3 JOULES/GRAM

## ELEMENTAL COMPOSITION (MOLE %)

C	22.941
H	29.028
O	38.187
N	9.700
K	0.096
S	0.048

## \* \* SUMMARY OF PROPELLANT GAS THERMODYNAMIC PROPERTIES \* \*

	L.D. G/CM <sup>3</sup>	TEMP K	PRESSURE MPA	IMPETUS J/G	MOL WT	CO-VOL CM <sup>3</sup> /G	I.B. GAMMA	CP J/MOL
1)	0.10	3082	115.03	1029.76	24.88	1.047	1.2287	45.17
2)	0.20	3093	258.49	1032.38	24.91	1.006	1.2316	45.60
3)	0.30	3100	435.72	1033.87	24.93	0.960	1.2370	46.09
	L.D. G/CM <sup>3</sup>	TEMP K	PRESSURE PSIA	IMPETUS FT-LB/LB	MOL WT	CO-VOL IN <sup>3</sup> /LB	I.B. GAMMA	CP CAL/MOL
1)	0.10	3082	16684.1	344567.4	24.88	28.969	1.2287	10.797
2)	0.20	3093	37491.3	345442.4	24.91	27.832	1.2316	10.898
3)	0.30	3100	63196.3	345939.7	24.93	26.578	1.2370	11.015

\*\*\* PROPELLANT AR2204 \*\*\*

PREDICTED COMBUSTION PRODUCTS  
CONSTITUENT CONCENTRATIONS - MOLES PER KG OF PROPELLANT

NAME		1)	2)	3)
CO	GAS	16.7319	16.7679	16.7919
H2O	GAS	9.36251	9.43234	9.48116
CO2	GAS	4.95733	4.90926	4.87351
N2	GAS	4.58270	4.57961	4.57440
H2	GAS	4.27298	4.21072	4.15520
KOH	GAS	$2.65627 \times 10^{-2}$	$3.53015 \times 10^{-2}$	$4.15638 \times 10^{-2}$
COS	GAS	$1.13965 \times 10^{-2}$	$1.79582 \times 10^{-2}$	$2.31810 \times 10^{-2}$
NO	GAS	$6.92814 \times 10^{-3}$	$4.69952 \times 10^{-3}$	$3.60266 \times 10^{-3}$
NH3	GAS	$3.77272 \times 10^{-3}$	$9.13374 \times 10^{-3}$	$1.66398 \times 10^{-2}$
HCN	GAS	$1.85133 \times 10^{-3}$	$4.76242 \times 10^{-3}$	$9.25666 \times 10^{-3}$
O2	GAS	$5.75516 \times 10^{-4}$	$2.50833 \times 10^{-4}$	$1.41004 \times 10^{-4}$
CH4	GAS	$5.00870 \times 10^{-5}$	$2.62758 \times 10^{-4}$	$7.91314 \times 10^{-4}$
K	GAS	$6.40617 \times 10^{-2}$	$5.53261 \times 10^{-2}$	$4.90717 \times 10^{-2}$
HNO	GAS	$3.79538 \times 10^{-5}$	$4.10587 \times 10^{-5}$	$4.34507 \times 10^{-5}$
S	GAS	$1.73473 \times 10^{-3}$	$1.10359 \times 10^{-3}$	$7.51337 \times 10^{-4}$
OH	GAS	$5.78438 \times 10^{-2}$	$3.86033 \times 10^{-2}$	$2.92207 \times 10^{-2}$
KO	GAS	$4.78925 \times 10^{-5}$	$4.35300 \times 10^{-5}$	$3.98045 \times 10^{-5}$
SO	GAS	$1.37209 \times 10^{-2}$	$8.75501 \times 10^{-3}$	$5.96803 \times 10^{-3}$
HS	GAS	$1.68410 \times 10^{-2}$	$1.60218 \times 10^{-2}$	$1.42380 \times 10^{-2}$
CH3	GAS	$2.10105 \times 10^{-5}$	$7.99466 \times 10^{-5}$	$1.99176 \times 10^{-4}$
H	GAS	$7.58871 \times 10^{-2}$	$4.98873 \times 10^{-2}$	$3.74384 \times 10^{-2}$
O	GAS	$6.45827 \times 10^{-4}$	$2.91508 \times 10^{-4}$	$1.70217 \times 10^{-4}$
CHO	GAS	$2.91821 \times 10^{-3}$	$4.90467 \times 10^{-3}$	$7.11443 \times 10^{-3}$
KSO4	GAS	$2.06586 \times 10^{-9}$	$5.50156 \times 10^{-9}$	$9.34439 \times 10^{-9}$
CN	GAS	$4.99476 \times 10^{-6}$	$8.96597 \times 10^{-6}$	$1.38126 \times 10^{-5}$
S2	GAS	$8.20476 \times 10^{-4}$	$7.47727 \times 10^{-4}$	$5.99087 \times 10^{-4}$
SO3	GAS	$2.29090 \times 10^{-6}$	$1.50594 \times 10^{-6}$	$1.04415 \times 10^{-6}$
C(S)	SOLID	0.0	0.0	0.0
KSO\$	SOLID	0.0	0.0	0.0
KSO\$	LIQUID	0.0	0.0	0.0
TOTAL GAS (MOLES/KG)		40.1931	40.1480	40.1162
DELTA Q (J/G)		-3455.4	-3464.4	-3468.4



## \*\*\* PROPELLANT AR2205 \*\*\*

## INGREDIENT AND FORMULATION INFORMATION

NAME	WT %	MOLE %	$\Delta H$ (CAL/MOL)	EMPIRICAL FORMULA
NC5	93.070	0.332	$-0.1646 \times 10^9$	C H O N 6000 7364 10271 2636
DP	0.890	5.260	$0.3107 \times 10^5$	C H N 12 11
KS	0.790	4.534	$-0.3427 \times 10^6$	K SO 2 4
C	0.100	8.334	0.0	C
DN	3.950	21.688	$-0.1710 \times 10^5$	C H O N 7 6 4 2
H2O	1.000	55.512	$-0.6832 \times 10^5$	H O 2
AL	0.200	4.342	$-0.6642 \times 10^5$	C H O 2 6

ENERGY OF FORMATION: -2528.3 JOULES/GRAM

## ELEMENTAL COMPOSITION (MOLE %)

C	23.396
H	29.140
O	37.603
N	9.718
K	0.096
S	0.048

## \* \* SUMMARY OF PROPELLANT GAS THERMODYNAMIC PROPERTIES \* \*

	L.D. G/CM <sup>3</sup>	TEMP K	PRESSURE MPA	IMPETUS J/G	MOL WT	CO-VOL CM <sup>3</sup> /G	I.B. GAMMA	CP J/MOL
1)	0.10	3002	113.95	1018.36	24.51	1.061	1.2333	44.45
2)	0.20	3012	256.36	1020.45	24.53	1.019	1.2363	44.87
3)	0.30	3018	432.68	1021.58	24.55	0.972	1.2419	45.37

	L.D. G/CM <sup>3</sup>	TEMP K	PRESSURE PSIA	IMPETUS FT-LB/LB	MOL WT	CO-VOL IN <sup>3</sup> /LB	I.B. GAMMA	CP CAL/MOL
1)	0.10	3002	16526.3	340749.2	24.51	29.376	1.2333	10.624
2)	0.20	3012	37181.4	341449.5	24.53	28.199	1.2363	10.723
3)	0.30	3018	62754.9	341829.8	24.56	26.902	1.2419	10.843

## \*\*\* PROPELLANT AR2205 \*\*\*

PREDICTED COMBUSTION PRODUCTS  
 CONSTITUENT CONCENTRATIONS - MOLES PER KG OF PROPELLANT

NAME		1)	2)	3)
CO	GAS	17.6941	17.7304	17.7502
H2O	GAS	8.91469	8.97880	9.02340
H2	GAS	4.83481	4.77103	4.71250
N2	GAS	4.60686	4.60235	4.59501
CO2	GAS	4.49709	4.44788	4.41396
KOH	GAS	$2.40818 \times 10^{-2}$	$3.23984 \times 10^{-2}$	$3.84906 \times 10^{-2}$
COS	GAS	$1.39044 \times 10^{-2}$	$2.07959 \times 10^{-2}$	$2.59467 \times 10^{-2}$
NH3	GAS	$4.70133 \times 10^{-3}$	$1.14552 \times 10^{-2}$	$2.09793 \times 10^{-2}$
NO	GAS	$4.15082 \times 10^{-3}$	$2.78482 \times 10^{-3}$	$2.12065 \times 10^{-3}$
HCN	GAS	$2.42449 \times 10^{-3}$	$6.28052 \times 10^{-3}$	$1.22926 \times 10^{-2}$
O2	GAS	$2.46639 \times 10^{-4}$	$1.05576 \times 10^{-4}$	$5.86836 \times 10^{-5}$
CH4	GAS	$9.62995 \times 10^{-5}$	$5.12514 \times 10^{-4}$	$1.56128 \times 10^{-3}$
K	GAS	$6.65601 \times 10^{-2}$	$5.82474 \times 10^{-2}$	$5.21594 \times 10^{-2}$
HNO	GAS	$2.37553 \times 10^{-5}$	$2.54838 \times 10^{-5}$	$2.68557 \times 10^{-5}$
S	GAS	$1.50347 \times 10^{-3}$	$8.98773 \times 10^{-4}$	$5.87249 \times 10^{-4}$
OH	GAS	$3.88330 \times 10^{-2}$	$2.56916 \times 10^{-2}$	$1.93475 \times 10^{-2}$
KO	GAS	$3.03165 \times 10^{-5}$	$2.76746 \times 10^{-5}$	$2.54266 \times 10^{-5}$
SO	GAS	$1.02688 \times 10^{-2}$	$6.14518 \times 10^{-3}$	$4.01294 \times 10^{-3}$
HS	GAS	$1.77565 \times 10^{-2}$	$1.59484 \times 10^{-2}$	$1.36411 \times 10^{-2}$
CH3	GAS	$3.06182 \times 10^{-5}$	$1.17614 \times 10^{-4}$	$2.95714 \times 10^{-4}$
H	GAS	$6.44099 \times 10^{-2}$	$4.21288 \times 10^{-2}$	$3.15346 \times 10^{-2}$
O	GAS	$3.28233 \times 10^{-4}$	$1.45944 \times 10^{-4}$	$8.44792 \times 10^{-5}$
CHO	GAS	$2.77071 \times 10^{-3}$	$4.65886 \times 10^{-3}$	$6.77538 \times 10^{-3}$
KSO4	GAS	$1.33757 \times 10^{-9}$	$3.44232 \times 10^{-9}$	$5.71501 \times 10^{-9}$
CN	GAS	$4.58504 \times 10^{-6}$	$8.22793 \times 10^{-6}$	$1.27166 \times 10^{-5}$
S2	GAS	$9.50997 \times 10^{-4}$	$7.73904 \times 10^{-4}$	$5.74611 \times 10^{-4}$
SO3	GAS	$1.07606 \times 10^{-6}$	$6.58564 \times 10^{-7}$	$4.35175 \times 10^{-7}$
C(S)	SOLID	0.0	0.0	0.0
KSO\$	SOLID	0.0	0.0	0.0
KSO\$	LIQUID	0.0	0.0	0.0
TOTAL GAS (MOLES/KG)		40.8006	40.7596	40.7256
DELTA Q (J/G)		-3337.0	-3343.1	-3345.9

## \*\*\* PROPELLANT AR2206 \*\*\*

## INGREDIENT AND FORMULATION INFORMATION

NAME	WT %	MOLE %	$\Delta H$ (CAL/MOL)	EMPIRICAL FORMULA
NC5	89.810	0.269	$-0.1646 \times 10^9$	C H O N 6000 7364 10271 2636
DP	0.980	4.866	$0.3107 \times 10^5$	C H N 12 11
KS	0.390	1.880	$-0.3427 \times 10^6$	K SO 2 4
KN	0.500	4.155	$-0.1178 \times 10^6$	KNO 3
C	0.100	7.002	0.0	C
DN	7.040	32.476	$-0.1710 \times 10^5$	C H O N 7 6 4 2
H2O	0.980	45.705	$-0.6832 \times 10^5$	H O 2
AL	0.200	3.648	$-0.6642 \times 10^5$	C H O 2 6

ENERGY OF FORMATION: -2448.0 JOULES/GRAM

## ELEMENTAL COMPOSITION (MOLE %)

C	23.891
H	29.241
O	36.972
N	9.774
K	0.099
S	0.023

## \* \* SUMMARY OF PROPELLANT GAS THERMODYNAMIC PROPERTIES \* \*

	L.D. G/CM <sup>3</sup>	TEMP K	PRESSURE MPA	IMPETUS J/G	MOL WT	CO-VOL CM <sup>3</sup> /G	I.B. GAMMA	CP J/MOL
1)	0.10	2924.	113.04	1008.33	24.11	1.078	1.2382	43.68
2)	0.20	2932.	254.68	1009.84	24.13	1.034	1.2414	44.10
3)	0.30	2936.	430.52	1010.61	24.15	0.986	1.2473	44.60

	L.D. G/CM <sup>3</sup>	TEMP K	PRESSURE PSIA	IMPETUS FT-LB/LB	MOL WT	CO-VOL IN <sup>3</sup> /LB	I.B. GAMMA	CP CAL/MOL
1)	0.10	2924.	16395.0	337395.1	24.11	29.850	1.2382	10.441
2)	0.20	2932.	36938.4	337900.9	24.13	28.627	1.2414	10.540
3)	0.30	2936.	62441.1	338157.2	24.15	27.279	1.2473	10.660

\*\*\* PROPELLANT AR2206 \*\*\*

PREDICTED COMBUSTION PRODUCTS  
CONSTITUENT CONCENTRATIONS - MOLES PER KG OF PROPELLANT

NAME		1)	2)	3)
CO	GAS	18.7213	18.7579	18.7729
H2O	GAS	8.38352	8.44098	8.48081
H2	GAS	5.48011	5.41480	5.35135
N2	GAS	4.65087	4.64435	4.63447
CO2	GAS	4.02967	3.98153	3.95185
KOH	GAS	$2.23719 \times 10^{-2}$	$3.04822 \times 10^{-2}$	$3.65704 \times 10^{-2}$
COS	GAS	$8.35682 \times 10^{-3}$	$1.18319 \times 10^{-2}$	$1.42474 \times 10^{-2}$
NH3	GAS	$5.89923 \times 10^{-3}$	$1.44689 \times 10^{-2}$	$2.66357 \times 10^{-2}$
NO	GAS	$2.42703 \times 10^{-3}$	$1.60875 \times 10^{-3}$	$1.21622 \times 10^{-3}$
HCN	GAS	$3.23285 \times 10^{-3}$	$8.43634 \times 10^{-3}$	$1.66300 \times 10^{-2}$
O2	GAS	$1.00927 \times 10^{-4}$	$4.23697 \times 10^{-5}$	$2.32726 \times 10^{-5}$
CH4	GAS	$1.90151 \times 10^{-4}$	$1.02756 \times 10^{-3}$	$3.16679 \times 10^{-3}$
K	GAS	$7.18272 \times 10^{-2}$	$6.37180 \times 10^{-2}$	$5.76331 \times 10^{-2}$
HNO	GAS	$1.45252 \times 10^{-5}$	$1.54394 \times 10^{-5}$	$1.61975 \times 10^{-5}$
S	GAS	$6.34397 \times 10^{-4}$	$3.55022 \times 10^{-4}$	$2.22029 \times 10^{-4}$
OH	GAS	$2.54641 \times 10^{-2}$	$1.66879 \times 10^{-2}$	$1.24966 \times 10^{-2}$
KO	GAS	$1.94373 \times 10^{-5}$	$1.78168 \times 10^{-5}$	$1.64543 \times 10^{-5}$
SO	GAS	$3.69292 \times 10^{-3}$	$2.06501 \times 10^{-3}$	$1.28885 \times 10^{-3}$
HS	GAS	$9.16671 \times 10^{-3}$	$7.74628 \times 10^{-3}$	$6.36106 \times 10^{-3}$
CH3	GAS	$4.54125 \times 10^{-5}$	$1.76169 \times 10^{-4}$	$4.47001 \times 10^{-4}$
H	GAS	$5.42758 \times 10^{-2}$	$3.52979 \times 10^{-2}$	$2.63335 \times 10^{-2}$
O	GAS	$1.61564 \times 10^{-4}$	$7.06757 \times 10^{-5}$	$4.05243 \times 10^{-5}$
CHO	GAS	$2.62082 \times 10^{-3}$	$4.40875 \times 10^{-3}$	$6.42909 \times 10^{-3}$
KSO4	GAS	$4.35965 \times 10^{-10}$	$1.08253 \times 10^{-9}$	$1.75855 \times 10^{-9}$
CN	GAS	$4.23740 \times 10^{-6}$	$7.59976 \times 10^{-6}$	$1.17820 \times 10^{-5}$
S2	GAS	$2.65309 \times 10^{-4}$	$1.91563 \times 10^{-4}$	$1.31234 \times 10^{-4}$
SO3	GAS	$2.35292 \times 10^{-7}$	$1.33550 \times 10^{-7}$	$8.39586 \times 10^{-8}$
C(S)	SOLID	0.0	0.0	0.0
KSO\$	SOLID	0.0	0.0	0.0
KSO\$	LIQUID	0.0	0.0	0.0
TOTAL GAS (MOLES/KG)		41.4762	41.4382	41.4013
DELTA Q (J/G)		-3221.5	-3225.5	-3228.0

## \*\*\* PROPELLANT AR4001 \*\*\*

## INGREDIENT AND FORMULATION INFORMATION

NAME	WT %	MOLE %	$\Delta H$ (CAL/MOL)	EMPIRICAL FORMULA
NC5	96.850	0.433	$-0.1646 \times 10^9$	C H O N 6000 7364 10271 2636
DP	1.380	10.235	$0.3107 \times 10^5$	C H N 12 11
KN	0.390	4.841	$-0.1178 \times 10^6$	KNO 3
DOP	0.200	0.643	$-0.2570 \times 10^6$	C H O 24 38 4
C	0.290	30.330	0.0	C
H2O	0.690	48.070	$-0.6832 \times 10^5$	H O 2
AL	0.200	5.449	$-0.6642 \times 10^5$	C H O 2 6

ENERGY OF FORMATION: -2512.1 JOULES/GRAM

## ELEMENTAL COMPOSITION (MOLE %)

C	23.318
H	29.002
O	37.930
N	9.709
K	0.041

## \* \* SUMMARY OF PROPELLANT GAS THERMODYNAMIC PROPERTIES \* \*

	L.D. G/CM <sup>3</sup>	TEMP K	PRESSURE MPA	IMPETUS J/G	MOL WT	CO-VOL CM <sup>3</sup> /G	I.B. GAMMA	CP J/MOL
1)	0.10	3072.	115.94	1036.47	24.64	1.059	1.2309	44.79
2)	0.20	3081.	260.83	1038.80	24.66	1.017	1.2338	45.20
3)	0.30	3087.	440.18	1040.06	24.68	0.970	1.2394	45.69

	L.D. G/CM <sup>3</sup>	TEMP K	PRESSURE PSIA	IMPETUS FT-LB/LB	MOL WT	CO-VOL IN <sup>3</sup> /LB	I.B. GAMMA	CP CAL/MOL
1)	0.10	3072.	16816.0	346817.8	24.64	29.308	1.2309	10.706
2)	0.20	3081.	37830.2	347591.1	24.66	28.141	1.2338	10.804
3)	0.30	3087.	63842.1	348011.3	24.68	26.853	1.2394	10.921

\*\*\* PROPELLANT AR4001 \*\*\*

PREDICTED COMBUSTION PRODUCTS  
CONSTITUENT CONCENTRATIONS - MOLES PER KG OF PROPELLANT

NAME		1)	2)	3)
CO	GAS	17.4275	17.4683	17.4931
H2O	GAS	9.10247	9.17001	9.21657
CO2	GAS	4.69591	4.64890	4.61638
N2	GAS	4.60067	4.59681	4.59057
H2	GAS	4.57987	4.51985	4.46470
KOH	GAS	$1.07891 \times 10^{-2}$	$1.44264 \times 10^{-2}$	$1.70630 \times 10^{-2}$
NO	GAS	$6.02723 \times 10^{-3}$	$4.05258 \times 10^{-3}$	$3.08677 \times 10^{-3}$
NH3	GAS	$4.21648 \times 10^{-3}$	$1.02542 \times 10^{-2}$	$1.87507 \times 10^{-2}$
HCN	GAS	$2.20177 \times 10^{-3}$	$5.68996 \times 10^{-3}$	$1.11100 \times 10^{-2}$
O2	GAS	$4.43946 \times 10^{-4}$	$1.90770 \times 10^{-4}$	$1.06121 \times 10^{-4}$
CH4	GAS	$6.77249 \times 10^{-5}$	$3.59451 \times 10^{-4}$	$1.09312 \times 10^{-3}$
K	GAS	$2.77673 \times 10^{-2}$	$2.41311 \times 10^{-2}$	$2.14977 \times 10^{-2}$
HNO	GAS	$3.41426 \times 10^{-5}$	$3.66786 \times 10^{-5}$	$3.86333 \times 10^{-5}$
OH	GAS	$5.23588 \times 10^{-2}$	$3.47036 \times 10^{-2}$	$2.61368 \times 10^{-2}$
KO	GAS	$1.80848 \times 10^{-5}$	$1.64212 \times 10^{-5}$	$1.50078 \times 10^{-5}$
CH3	GAS	$2.67065 \times 10^{-5}$	$1.02330 \times 10^{-4}$	$2.56623 \times 10^{-4}$
H	GAS	$7.62899 \times 10^{-2}$	$4.99287 \times 10^{-2}$	$3.73446 \times 10^{-2}$
O	GAS	$5.49051 \times 10^{-4}$	$2.44752 \times 10^{-4}$	$1.41617 \times 10^{-4}$
CHO	GAS	$3.08438 \times 10^{-3}$	$5.18423 \times 10^{-3}$	$7.52902 \times 10^{-3}$
CN	GAS	$5.52853 \times 10^{-6}$	$9.90639 \times 10^{-6}$	$1.52638 \times 10^{-5}$
C(S)	SOLID	0.0	0.0	0.0
TOTAL GAS (MOLES/KG)		40.5903	40.5532	40.5255
DELTA Q (J/G)		-3444.0	-3453.4	-3458.2

## \*\*\* PROPELLANT AR4002 \*\*\*

## INGREDIENT AND FORMULATION INFORMATION

NAME	WT %	MOLE %	$\Delta H$ (CAL/MOL)	EMPIRICAL FORMULA
NC6	97.710	0.463	$-0.1638 \times 10^9$	C H O N 6000 7329 10341 2671
DP	0.890	7.033	$0.3107 \times 10^5$	C H N 12 11
KN	0.100	1.323	$-0.1178 \times 10^6$	KNO 3
C	0.100	11.144	0.0	C
H2O	1.000	74.232	$-0.6832 \times 10^5$	H O 2
AL	0.200	5.806	$-0.6642 \times 10^5$	C H O 2 6

ENERGY OF FORMATION: -2540.9 JOULES/GRAM

## ELEMENTAL COMPOSITION (MOLE %)

C	22.794
H	28.869
O	38.490
N	9.836
K	0.010

## \* \* SUMMARY OF PROPELLANT GAS THERMODYNAMIC PROPERTIES \* \*

	L.D. G/CM <sup>3</sup>	TEMP K	PRESSURE MPA	IMPETUS J/G	MOL WT	CO-VOL CM <sup>3</sup> /G	I.B. GAMMA	CP J/MOL
1)	0.10	3172	117.74	1054.22	25.01	1.045	1.2259	45.59
2)	0.20	3185	264.65	1057.38	25.04	1.004	1.2287	46.00
3)	0.30	3193	446.13	1059.11	25.06	0.959	1.2340	46.48

	L.D. G/CM <sup>3</sup>	TEMP K	PRESSURE PSIA	IMPETUS FT-LB/LB	MOL WT	CO-VOL IN <sup>3</sup> /LB	I.B. GAMMA	CP CAL/MOL
1)	0.10	3172	17076.8	352746.8	25.02	28.921	1.2259	10.896
2)	0.20	3185	38384.7	353807.5	25.04	27.791	1.2287	10.995
3)	0.30	3193	64705.1	354385.7	25.06	26.543	1.2340	11.110

## \*\*\* PROPELLANT AR4002 \*\*\*

PREDICTED COMBUSTION PRODUCTS  
 CONSTITUENT CONCENTRATIONS - MOLES PER KG OF PROPELLANT

NAME		1)	2)	3)
CO	GAS	16.3726	16.4104	16.4374
H2O	GAS	9.56196	9.63989	9.69319
CO2	GAS	5.19040	5.14671	5.11363
N2	GAS	4.64550	4.64344	4.63926
H2	GAS	3.99822	3.93934	3.88664
NO	GAS	$1.09810 \times 10^{-2}$	$7.49362 \times 10^{-3}$	$5.75612 \times 10^{-3}$
NH3	GAS	$3.33130 \times 10^{-3}$	$8.04321 \times 10^{-3}$	$1.46174 \times 10^{-2}$
KOH	GAS	$3.07077 \times 10^{-3}$	$4.05273 \times 10^{-3}$	$4.74698 \times 10^{-3}$
HCN	GAS	$1.66247 \times 10^{-3}$	$4.26115 \times 10^{-3}$	$8.25077 \times 10^{-3}$
O2	GAS	$1.17350 \times 10^{-3}$	$5.16868 \times 10^{-4}$	$2.91881 \times 10^{-4}$
CH4	GAS	$3.26483 \times 10^{-5}$	$1.70255 \times 10^{-4}$	$5.10639 \times 10^{-4}$
K	GAS	$6.81240 \times 10^{-3}$	$5.83091 \times 10^{-3}$	$5.13776 \times 10^{-3}$
HNO	GAS	$5.94647 \times 10^{-5}$	$6.47008 \times 10^{-5}$	$6.85808 \times 10^{-5}$
OH	GAS	$8.30976 \times 10^{-2}$	$5.57559 \times 10^{-2}$	$4.22891 \times 10^{-2}$
KO	GAS	$7.86739 \times 10^{-6}$	$7.12799 \times 10^{-6}$	$6.48835 \times 10^{-6}$
CH3	GAS	$1.78304 \times 10^{-5}$	$6.76067 \times 10^{-5}$	$1.67775 \times 10^{-4}$
H	GAS	$9.34297 \times 10^{-2}$	$6.15760 \times 10^{-2}$	$4.62164 \times 10^{-2}$
O	GAS	$1.20912 \times 10^{-3}$	$5.50307 \times 10^{-4}$	$3.22180 \times 10^{-4}$
CHO	GAS	$3.32207 \times 10^{-3}$	$5.58883 \times 10^{-3}$	$8.09825 \times 10^{-3}$
CN	GAS	$6.35264 \times 10^{-6}$	$1.14092 \times 10^{-5}$	$1.75278 \times 10^{-5}$
C(S)	SOLID	0.0	0.0	0.0
TOTAL GAS (MOLES/KG)		39.9769	39.9338	39.9066
DELTA Q (J/G)		-3598.6	-3613.2	-3620.5



## \*\*\* PROPELLANT AR5401 \*\*\*

## INGREDIENT AND FORMULATION INFORMATION

NAME	WT %	MOLE %	$\Delta H$ (CAL/MOL)	EMPIRICAL FORMULA
NC5	96.000	0.379	$-0.1646 \times 10^9$	C H O N 6000 7364 10271 2636
DP	1.180	7.731	$0.3107 \times 10^5$	C H N 12 11
KS	0.790	5.026	$-0.3427 \times 10^6$	K SO 2 4
C	0.200	18.478	0.0	C
EC	0.640	2.644	$-0.2510 \times 10^5$	C H ON 17 20 2
H2O	0.990	60.928	$-0.6832 \times 10^5$	H O 2
AL	0.200	4.813	$-0.6642 \times 10^5$	C H O 2 6

ENERGY OF FORMATION: -2583.3 JOULES/GRAM

## ELEMENTAL COMPOSITION (MOLE %)

C	23.175
H	29.252
O	37.817
N	9.613
K	0.095
S	0.048

## \* \* SUMMARY OF PROPELLANT GAS THERMODYNAMIC PROPERTIES \* \*

	L.D. G/CM <sup>3</sup>	TEMP K	PRESSURE MPA	IMPETUS J/G	MOL WT	CO-VOL CM <sup>3</sup> /G	I.B. GAMMA	CP J/MOL
1)	0.10	3019.	113.97	1019.32	24.62	1.055	1.2316	44.72
2)	0.20	3028.	256.28	1021.54	24.64	1.013	1.2347	45.14
3)	0.30	3034.	432.33	1022.83	24.66	0.967	1.2403	45.64

	L.D. G/CM <sup>3</sup>	TEMP K	PRESSURE PSIA	IMPETUS FT-LB/LB	MOL WT	CO-VOL IN <sup>3</sup> /LB	I.B. GAMMA	CP CAL/MOL
1)	0.10	3019.	16530.3	341068.9	24.62	29.203	1.2316	10.689
2)	0.20	3028.	37169.8	341816.4	24.64	28.047	1.2347	10.789
3)	0.30	3034.	62704.1	342246.8	24.66	26.769	1.2403	10.909

## \*\*\* PROPELLANT AR5401 \*\*\*

PREDICTED COMBUSTION PRODUCTS  
 CONSTITUENT CONCENTRATIONS - MOLES PER KG OF PROPELLANT

NAME		1)	2)	3)
CO	GAS	17.3211	17.3584	17.3812
H2O	GAS	9.15094	9.21741	9.26404
CO2	GAS	4.67297	4.62333	4.58780
H2	GAS	4.65604	4.59209	4.53396
N2	GAS	4.55996	4.55582	4.54931
KOH	GAS	$2.49730 \times 10^{-2}$	$3.34403 \times 10^{-2}$	$3.95954 \times 10^{-2}$
COS	GAS	$1.32265 \times 10^{-2}$	$2.00569 \times 10^{-2}$	$2.52431 \times 10^{-2}$
NH3	GAS	$4.38985 \times 10^{-3}$	$1.06761 \times 10^{-2}$	$1.95244 \times 10^{-2}$
NO	GAS	$4.72651 \times 10^{-3}$	$3.17986 \times 10^{-3}$	$2.42677 \times 10^{-3}$
HCN	GAS	$2.18387 \times 10^{-3}$	$5.64592 \times 10^{-3}$	$1.10300 \times 10^{-2}$
O2	GAS	$3.11053 \times 10^{-4}$	$1.33762 \times 10^{-4}$	$7.46161 \times 10^{-5}$
CH4	GAS	$7.89948 \times 10^{-5}$	$4.18587 \times 10^{-4}$	$1.27043 \times 10^{-3}$
K	GAS	$6.56635 \times 10^{-2}$	$5.71997 \times 10^{-2}$	$5.10514 \times 10^{-2}$
HNO	GAS	$2.66365 \times 10^{-5}$	$2.86263 \times 10^{-5}$	$3.02100 \times 10^{-5}$
S	GAS	$1.55135 \times 10^{-3}$	$9.43022 \times 10^{-4}$	$6.23112 \times 10^{-4}$
OH	GAS	$4.31224 \times 10^{-2}$	$2.85898 \times 10^{-2}$	$2.15652 \times 10^{-2}$
KO	GAS	$3.40837 \times 10^{-5}$	$3.10337 \times 10^{-5}$	$2.84627 \times 10^{-5}$
SO	GAS	$1.12316 \times 10^{-2}$	$6.83731 \times 10^{-3}$	$4.51690 \times 10^{-3}$
HS	GAS	$1.74829 \times 10^{-2}$	$1.59455 \times 10^{-2}$	$1.37782 \times 10^{-2}$
CH3	GAS	$2.67651 \times 10^{-5}$	$1.02492 \times 10^{-4}$	$2.56973 \times 10^{-4}$
H	GAS	$6.62564 \times 10^{-2}$	$4.33935 \times 10^{-2}$	$3.25130 \times 10^{-2}$
O	GAS	$3.88567 \times 10^{-4}$	$1.73439 \times 10^{-4}$	$1.00691 \times 10^{-4}$
CHO	GAS	$2.75602 \times 10^{-3}$	$4.63168 \times 10^{-3}$	$6.73072 \times 10^{-3}$
KSO4	GAS	$1.61900 \times 10^{-9}$	$4.19226 \times 10^{-9}$	$6.98612 \times 10^{-9}$
CN	GAS	$4.47284 \times 10^{-6}$	$8.02433 \times 10^{-6}$	$1.23945 \times 10^{-5}$
S2	GAS	$9.24965 \times 10^{-4}$	$7.75952 \times 10^{-4}$	$5.87869 \times 10^{-4}$
SO3	GAS	$1.37056 \times 10^{-6}$	$8.54646 \times 10^{-7}$	$5.72071 \times 10^{-7}$
C(S)	SOLID	0.0	0.0	0.0
KSO\$	SOLID	0.0	0.0	0.0
KSO\$	LIQUID	0.0	0.0	0.0
TOTAL GAS (MOLES/KG)		40.6203	40.5793	40.5472
DELTA Q (J/G)		-3366.4	-3373.2	-3376.2

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APPENDIX II

PROPELLANTS OF BRITISH ORIGIN

This appendix presents calculated thermodynamic data for the following propellant formulations:

NH.055	20 pr tank gun
FNH.016	105 mm M2A2 howitzer
FNH.023	105 mm M2A2 howitzer
FNH/P	5.5 inch medium gun
NQ	20 pr tank gun
	155 mm FH70 howitzer; Cartridge 3
	105 mm L118 howitzer; Charge L36A3
MNF2P/S	4.5 inch naval gun
MNLF	4.5 inch naval gun
MNQF	40 mm Bofors gun
N and N/S	155 mm FH70 howitzer; Cartridge 2
	105 mm L118 howitzer; Charges L35A2 and L36A2

(See page 7 for table of ingredient abbreviations)

## \*\*\* PROPELLANT NH \*\*\*

## INGREDIENT AND FORMULATION INFORMATION

NAME	WT %	MOLE %	$\Delta H$ (CAL/MOL)	EMPIRICAL FORMULA
NC5	83.640	0.261	$-0.1646 \times 10^9$	C H O N 6000 7364 10271 2636
DP	0.970	5.027	$0.3107 \times 10^5$	C H N 12 11
DN	9.720	46.805	$-0.1710 \times 10^5$	C H O N 7 6 4 2
DB	4.880	15.376	$-0.2014 \times 10^6$	C H O 16 22 4
H2O	0.590	28.723	$-0.6832 \times 10^5$	H O 2
AL	0.200	3.808	$-0.6642 \times 10^5$	C H O 2 6

ENERGY OF FORMATION: -2336.6 JOULES/GRAM

## ELEMENTAL COMPOSITION (MOLE %)

C	25.569
H	31.003
O	34.315
N	9.113

## \* \* SUMMARY OF PROPELLANT GAS THERMODYNAMIC PROPERTIES \* \*

	L.D. G/CM <sup>3</sup>	TEMP K	PRESSURE MPA	IMPETUS J/G	MOL WT	CO-VOL CM <sup>3</sup> /G	I.B. GAMMA	CP J/MOL
1)	0.10	2479.	104.72	925.83	22.26	1.158	1.2608	40.67
2)	0.20	2486.	237.83	926.32	22.31	1.104	1.2643	41.19
3)	0.30	2497.	405.33	926.76	22.40	1.047	1.2703	41.91

	L.D. G/CM <sup>3</sup>	TEMP K	PRESSURE PSIA	IMPETUS FT-LB/LB	MOL WT	CO-VOL IN <sup>3</sup> /LB	I.B. GAMMA	CP CAL/MOL
1)	0.10	2479.	15189.0	309796.7	22.26	32.045	1.2608	9.721
2)	0.20	2486.	34494.1	309953.4	22.31	30.571	1.2643	9.844
3)	0.30	2497.	58787.6	310101.1	22.40	28.967	1.2703	10.017

## \*\*\* PROPELLANT NH \*\*\*

PREDICTED COMBUSTION PRODUCTS  
 CONSTITUENT CONCENTRATIONS - MOLES PER KG OF PROPELLANT

NAME		1)	2)	3)
CO	GAS	22.6720	22.6522	22.5487
H2	GAS	9.09593	8.93936	8.69089
H2O	GAS	6.12726	6.19227	6.26063
N2	GAS	4.47589	4.45585	4.42678
CO2	GAS	2.50201	2.47936	2.49709
NH3	GAS	$1.60279 \times 10^{-2}$	$3.98492 \times 10^{-2}$	$7.27295 \times 10^{-2}$
HCN	GAS	$9.85061 \times 10^{-3}$	$2.62558 \times 10^{-2}$	$5.19068 \times 10^{-2}$
NO	GAS	$8.97727 \times 10^{-5}$	$5.95378 \times 10^{-5}$	$4.74871 \times 10^{-5}$
CH4	GAS	$5.48141 \times 10^{-3}$	$3.00509 \times 10^{-2}$	$8.86389 \times 10^{-2}$
O2	GAS	$5.31620 \times 10^{-7}$	$2.22473 \times 10^{-7}$	$1.32798 \times 10^{-7}$
HNO	GAS	$6.12176 \times 10^{-7}$	$6.55969 \times 10^{-7}$	$7.28670 \times 10^{-7}$
OH	GAS	$1.82332 \times 10^{-3}$	$1.19263 \times 10^{-3}$	$9.29714 \times 10^{-4}$
CH3	GAS	$2.12325 \times 10^{-4}$	$8.39748 \times 10^{-4}$	$2.11423 \times 10^{-3}$
H	GAS	$1.38692 \times 10^{-2}$	$8.97808 \times 10^{-3}$	$6.81122 \times 10^{-3}$
O	GAS	$1.90719 \times 10^{-6}$	$8.33987 \times 10^{-7}$	$5.14278 \times 10^{-7}$
CHO	GAS	$1.22939 \times 10^{-3}$	$2.10129 \times 10^{-3}$	$3.15632 \times 10^{-3}$
CN	GAS	$1.20865 \times 10^{-6}$	$2.21790 \times 10^{-6}$	$3.59599 \times 10^{-6}$
C(S)	SOLID	0.0	0.0	0.0
TOTAL GAS (MOLES/KG)		44.9216	44.8284	44.6504
DELTA Q (J/G)		-2633.6	-2642.2	-2660.5

## \*\*\* PROPELLANT FNH.016 \*\*\*

## INGREDIENT AND FORMULATION INFORMATION

NAME	WT %	MOLE %	$\Delta H$ (CAL/MOL)	EMPIRICAL FORMULA
NC5	83.240	0.238	$-0.1646 \times 10^9$	C H O N 6000 7364 10271 2636
DP	0.990	4.704	$0.3107 \times 10^5$	C H N 12 11
DN	9.910	43.753	$-0.1710 \times 10^5$	C H O N 7 6 4 2
DB	4.960	14.329	$-0.2014 \times 10^6$	C H O 16 22 4
C	0.100	6.701	0.0	C
H2O	0.600	26.782	$-0.6832 \times 10^5$	H O 2
AL	0.200	3.491	$-0.6642 \times 10^5$	C H O 2 6

ENERGY OF FORMATION: -2331.4 JOULES/GRAM

## ELEMENTAL COMPOSITION (MOLE %)

C	25.683
H	31.026
O	34.200
N	9.090

## \* \* SUMMARY OF PROPELLANT GAS THERMODYNAMIC PROPERTIES \* \*

	L.D. G/CM <sup>3</sup>	TEMP K	PRESSURE MPA	IMPETUS J/G	MOL WT	CO-VOL CM <sup>3</sup> /G	I.B. GAMMA	CP J/MOL
1)	0.10	2454.	104.05	919.47	22.19	1.162	1.2620	40.52
2)	0.20	2462.	236.41	919.99	22.24	1.108	1.2655	41.05
3)	0.30	2474.	403.11	920.52	22.34	1.049	1.2714	41.80

	L.D. G/CM <sup>3</sup>	TEMP K	PRESSURE PSIA	IMPETUS FT-LB/LB	MOL WT	CO-VOL IN <sup>3</sup> /LB	I.B. GAMMA	CP CAL/MOL
1)	0.10	2454.	15091.6	307670.8	22.19	32.156	1.2620	9.685
2)	0.20	2462.	34288.7	307834.6	22.24	30.667	1.2655	9.810
3)	0.30	2474.	58466.8	308014.7	22.34	29.048	1.2714	9.990

## \*\*\* PROPELLANT FNH.016 \*\*\*

PREDICTED COMBUSTION PRODUCTS  
 CONSTITUENT CONCENTRATIONS - MOLES PER KG OF PROPELLANT

NAME		1)	2)	3)
CO	GAS	22.8639	22.8358	22.7159
H2	GAS	9.26978	9.09882	8.82237
H2O	GAS	5.97310	6.04079	6.11488
N2	GAS	4.46748	4.44648	4.41623
CO2	GAS	2.43950	2.41970	2.44272
NH3	GAS	$1.67750 \times 10^{-2}$	$4.16518 \times 10^{-2}$	$7.56912 \times 10^{-2}$
HCN	GAS	$1.03941 \times 10^{-2}$	$2.76803 \times 10^{-2}$	$5.45163 \times 10^{-2}$
NO	GAS	$7.28938 \times 10^{-5}$	$4.86260 \times 10^{-5}$	$3.93038 \times 10^{-5}$
CH4	GAS	$6.57147 \times 10^{-3}$	$3.58356 \times 10^{-2}$	$1.04262 \times 10^{-1}$
O2	GAS	$3.83077 \times 10^{-7}$	$1.61778 \times 10^{-7}$	$9.86450 \times 10^{-8}$
HNO	GAS	$4.97853 \times 10^{-7}$	$5.36532 \times 10^{-7}$	$6.03627 \times 10^{-7}$
OH	GAS	$1.53475 \times 10^{-3}$	$1.00837 \times 10^{-3}$	$7.94359 \times 10^{-4}$
CH3	GAS	$2.27098 \times 10^{-4}$	$8.96442 \times 10^{-4}$	$2.24346 \times 10^{-3}$
H	GAS	$1.25789 \times 10^{-2}$	$8.16024 \times 10^{-3}$	$6.22288 \times 10^{-3}$
O	GAS	$1.43519 \times 10^{-6}$	$6.32491 \times 10^{-7}$	$3.97126 \times 10^{-7}$
CHO	GAS	$1.15624 \times 10^{-3}$	$1.98040 \times 10^{-3}$	$2.98592 \times 10^{-3}$
CN	GAS	$1.09750 \times 10^{-6}$	$2.02057 \times 10^{-6}$	$3.29564 \times 10^{-6}$
C(S)	SOLID	0.0	0.0	0.0
TOTAL GAS (MOLES/KG)		45.0630	44.9588	44.7588
DELTA Q (J/G)		-2598.6	-2608.3	-2628.9



## \*\*\* PROPELLANT FNH.023 \*\*\*

## INGREDIENT AND FORMULATION INFORMATION

NAME	WT %	MOLE %	$\Delta H$ (CAL/MOL)	EMPIRICAL FORMULA
NC5	83.330	0.256	$-0.1646 \times 10^9$	C H O N 6000 7364 10271 2636
DP	0.990	5.040	$0.3107 \times 10^5$	C H N 12 11
DN	9.920	46.921	$-0.1710 \times 10^5$	C H O N 7 6 4 2
DB	4.960	15.351	$-0.2014 \times 10^6$	C H O 16 22 4
H2O	0.600	28.692	$-0.6832 \times 10^5$	H O 2
AL	0.200	3.740	$-0.6642 \times 10^5$	C H O 2 6

ENERGY OF FORMATION: -2353.6 JOULES/GRAM

## ELEMENTAL COMPOSITION (MOLE %)

C	25.619
H	31.050
O	34.232
N	9.099

## \* \* SUMMARY OF PROPELLANT GAS THERMODYNAMIC PROPERTIES \* \*

	L.D. G/CM <sup>3</sup>	TEMP K	PRESSURE MPA	IMPETUS J/G	MOL WT	CO-VOL CM <sup>3</sup> /G	I.B. GAMMA	CP J/MOL
1)	0.10	2464.	104.35	922.33	22.21	1.160	1.2615	40.58
2)	0.20	2471.	237.06	922.83	22.26	1.107	1.2650	41.10
3)	0.30	2483.	404.15	923.33	22.36	1.048	1.2710	41.85

	L.D. G/CM <sup>3</sup>	TEMP K	PRESSURE PSIA	IMPETUS FT-LB/LB	MOL WT	CO-VOL IN <sup>3</sup> /LB	I.B. GAMMA	CP CAL/MOL
1)	0.10	2464.	15135.8	308626.6	22.21	32.114	1.2615	9.700
2)	0.20	2471.	34383.3	308787.3	22.26	30.631	1.2650	9.824
3)	0.30	2483.	58616.9	308953.9	22.36	29.018	1.2710	10.001

## \*\*\* PROPELLANT FNH.023 \*\*\*

PREDICTED COMBUSTION PRODUCTS  
 CONSTITUENT CONCENTRATIONS - MOLES PER KG OF PROPELLANT

NAME		1)	2)	3)
CO	GAS	22.7802	22.7555	22.6422
H2	GAS	9.21380	9.04847	8.78293
H2O	GAS	6.04362	6.11031	6.18222
N2	GAS	4.47250	4.45185	4.42201
CO2	GAS	2.46359	2.44257	2.46340
NH3	GAS	$1.65135 \times 10^{-2}$	$4.10272 \times 10^{-2}$	$7.46904 \times 10^{-2}$
HCN	GAS	$1.01801 \times 10^{-2}$	$2.71224 \times 10^{-2}$	$5.35023 \times 10^{-2}$
NO	GAS	$7.92383 \times 10^{-5}$	$5.27307 \times 10^{-5}$	$4.23917 \times 10^{-5}$
CH4	GAS	$6.12866 \times 10^{-3}$	$3.34967 \times 10^{-2}$	$9.80033 \times 10^{-2}$
O2	GAS	$4.36689 \times 10^{-7}$	$1.83720 \times 10^{-7}$	$1.11059 \times 10^{-7}$
HNO	GAS	$5.41260 \times 10^{-7}$	$5.81952 \times 10^{-7}$	$6.51385 \times 10^{-7}$
OH	GAS	$1.64542 \times 10^{-3}$	$1.07909 \times 10^{-3}$	$8.46465 \times 10^{-4}$
CH3	GAS	$2.21513 \times 10^{-4}$	$8.75174 \times 10^{-4}$	$2.19573 \times 10^{-3}$
H	GAS	$1.30892 \times 10^{-2}$	$8.48374 \times 10^{-3}$	$6.45610 \times 10^{-3}$
O	GAS	$1.60791 \times 10^{-6}$	$7.06331 \times 10^{-7}$	$4.40763 \times 10^{-7}$
CHO	GAS	$1.18551 \times 10^{-3}$	$2.02889 \times 10^{-3}$	$3.05452 \times 10^{-3}$
CN	GAS	$1.14052 \times 10^{-6}$	$2.09713 \times 10^{-6}$	$3.41252 \times 10^{-6}$
C(S)	SOLID	0.0	0.0	0.0
TOTAL GAS (MOLES/KG)		45.0228	44.9229	44.7316
DELTA Q (J/G)		-2613.4	-2622.7	-2642.4

## \*\*\* PROPELLANT FNH/P \*\*\*

## INGREDIENT AND FORMULATION INFORMATION

NAME	WT %	MOLE %	$\Delta H$ (CAL/MOL)	EMPIRICAL FORMULA
NC5	82.340	0.241	$-0.1646 \times 10^9$	C H O N 6000 7364 10271 2636
DP	0.990	4.805	$0.3107 \times 10^5$	C H N 12 11
DN	9.920	44.733	$-0.1710 \times 10^5$	C H O N 7 6 4 2
DB	4.960	14.635	$-0.2014 \times 10^6$	C H O 16 22 4
KS	0.990	4.666	$-0.3427 \times 10^6$	K SO 2 4
H2O	0.600	27.354	$-0.6832 \times 10^5$	H O 2
AL	0.200	3.566	$-0.6642 \times 10^5$	C H O 2 6

ENERGY OF FORMATION: -2390.8 JOULES/GRAM

## ELEMENTAL COMPOSITION (MOLE %)

C	25.542
H	30.952
O	34.279
N	9.053
K	0.116
S	0.058

## \* \* SUMMARY OF PROPELLANT GAS THERMODYNAMIC PROPERTIES \* \*

	L.D. G/CM <sup>3</sup>	TEMP K	PRESSURE MPA	IMPETUS J/G	MOL WT	CO-VOL CM <sup>3</sup> /G	I.B. GAMMA	CP J/MOL
1)	0.10	2429.	102.15	903.74	22.35	1.151	1.2619	40.57
2)	0.20	2437.	231.86	904.45	22.40	1.098	1.2654	41.10
3)	0.30	2450.	394.93	905.10	22.50	1.041	1.2713	41.85
	L.D. G/CM <sup>3</sup>	TEMP K	PRESSURE PSIA	IMPETUS FT-LB/LB	MOL WT	CO-VOL IN <sup>3</sup> /LB	I.B. GAMMA	CP CAL/MOL
1)	0.10	2429.	14815.5	302399.3	22.35	31.867	1.2619	9.697
2)	0.20	2437.	33627.9	302636.7	22.40	30.405	1.2654	9.824
3)	0.30	2450.	57280.0	302854.9	22.50	28.819	1.2713	10.004

## \*\*\* PROPELLANT FNH/P \*\*\*

PREDICTED COMBUSTION PRODUCTS  
 CONSTITUENT CONCENTRATIONS - MOLES PER KG OF PROPELLANT

NAME		1)	2)	3)
CO	GAS	22.4781	22.4515	22.3362
H2	GAS	9.06073	8.89309	8.62423
H2O	GAS	6.05425	6.11979	6.18942
N2	GAS	4.42650	4.40647	4.37755
CO2	GAS	2.51487	2.48945	2.50778
COS	GAS	$3.99428 \times 10^{-2}$	$4.60692 \times 10^{-2}$	$4.92334 \times 10^{-2}$
NH3	GAS	$1.64090 \times 10^{-2}$	$4.06988 \times 10^{-2}$	$7.38517 \times 10^{-2}$
KOH	GAS	$1.42740 \times 10^{-2}$	$2.06260 \times 10^{-2}$	$2.61643 \times 10^{-2}$
HCN	GAS	$9.59786 \times 10^{-3}$	$2.55675 \times 10^{-2}$	$5.03171 \times 10^{-2}$
CH4	GAS	$6.51560 \times 10^{-3}$	$3.53743 \times 10^{-2}$	$1.02537 \times 10^{-1}$
NO	GAS	$6.36152 \times 10^{-5}$	$4.26534 \times 10^{-5}$	$3.45840 \times 10^{-5}$
O2	GAS	$3.22317 \times 10^{-7}$	$1.37087 \times 10^{-7}$	$8.39385 \times 10^{-8}$
K	GAS	$9.93524 \times 10^{-2}$	$9.30023 \times 10^{-2}$	$8.74648 \times 10^{-2}$
HNO	GAS	$4.25401 \times 10^{-7}$	$4.60385 \times 10^{-7}$	$5.19007 \times 10^{-7}$
S	GAS	$2.40601 \times 10^{-4}$	$1.09293 \times 10^{-4}$	$6.28148 \times 10^{-5}$
OH	GAS	$1.36603 \times 10^{-3}$	$9.01123 \times 10^{-4}$	$7.11581 \times 10^{-4}$
KO	GAS	$8.50753 \times 10^{-7}$	$8.38747 \times 10^{-7}$	$8.68264 \times 10^{-7}$
SO	GAS	$7.52335 \times 10^{-4}$	$3.41260 \times 10^{-4}$	$1.98000 \times 10^{-4}$
HS	GAS	$1.32965 \times 10^{-2}$	$9.07977 \times 10^{-3}$	$6.66304 \times 10^{-3}$
CH3	GAS	$2.04339 \times 10^{-4}$	$8.05725 \times 10^{-4}$	$2.01306 \times 10^{-3}$
H	GAS	$1.11448 \times 10^{-2}$	$7.26244 \times 10^{-3}$	$5.55619 \times 10^{-3}$
O	GAS	$1.16300 \times 10^{-6}$	$5.16778 \times 10^{-7}$	$3.26176 \times 10^{-7}$
CHO	GAS	$1.03319 \times 10^{-3}$	$1.77143 \times 10^{-3}$	$2.66990 \times 10^{-3}$
KSO4	GAS	$1.66117 \times 10^{-10}$	$3.76989 \times 10^{-10}$	$6.25832 \times 10^{-10}$
CN	GAS	$8.86211 \times 10^{-7}$	$1.63925 \times 10^{-6}$	$2.67956 \times 10^{-6}$
S2	GAS	$1.29066 \times 10^{-3}$	$6.07527 \times 10^{-4}$	$3.28875 \times 10^{-4}$
SO3	GAS	$3.46988 \times 10^{-9}$	$1.61048 \times 10^{-9}$	$9.93049 \times 10^{-10}$
C(S)	SOLID	0.0	0.0	0.0
KSO\$	SOLID	0.0	0.0	0.0
KSO\$	LIQUID	0.0	0.0	0.0
TOTAL GAS (MOLES/KG)		44.7499	44.6426	44.4430
DELTA Q (J/G)		-2546.1	-2553.1	-2571.2

## \*\*\* PROPELLANT NQ \*\*\*

## INGREDIENT AND FORMULATION INFORMATION

NAME	WT %	MOLE %	$\Delta H$ (CAL/MOL)	EMPIRICAL FORMULA
NC4	20.690	0.012	$-0.1659 \times 10^9$	C H O N 6000 7416 10168 2584
NG	20.500	14.101	$-0.8860 \times 10^5$	C H O N 3 5 9 3
NQ	54.730	82.146	$-0.2210 \times 10^5$	CH O N 4 2 4
EC	3.580	2.084	$-0.2510 \times 10^5$	C H ON 17 20 2
CRY	0.300	0.223	$-0.7890 \times 10^6$	Na AlF 3 6
AC	0.050	0.134	$-0.5927 \times 10^5$	C H O 3 6
H2O	0.150	1.301	$-0.6832 \times 10^5$	H O 2

ENERGY OF FORMATION: -1423.9 JOULES/GRAM

## ELEMENTAL COMPOSITION (MOLE %)

C	14.550
H	33.556
O	26.120
N	25.633
Na	0.042
Al	0.014
F	0.085

## \* \* SUMMARY OF PROPELLANT GAS THERMODYNAMIC PROPERTIES \* \*

	L.D. G/CM <sup>3</sup>	TEMP K	PRESSURE MPA	IMPETUS J/G	MOL WT	CO-VOL CM <sup>3</sup> /G	I.B. GAMMA	CP J/MOL
1)	0.10	2763	115.93	1027.76	22.34	1.133	1.2459	42.59
2)	0.20	2766	262.38	1027.17	22.37	1.084	1.2494	43.02
3)	0.30	2769	445.84	1026.40	22.40	1.031	1.2558	43.60
	L.D. G/CM <sup>3</sup>	TEMP K	PRESSURE PSIA	IMPETUS FT-LB/LB	MOL WT	CO-VOL IN <sup>3</sup> /LB	I.B. GAMMA	CP CAL/MOL
1)	0.10	2763	16813.5	343896.6	22.34	31.356	1.2459	10.178
2)	0.20	2766	38054.4	343699.4	22.37	30.018	1.2494	10.282
3)	0.30	2769	64663.7	343440.4	22.40	28.532	1.2558	10.421

## \*\*\* PROPELLANT NQ \*\*\*

PREDICTED COMBUSTION PRODUCTS  
CONSTITUENT CONCENTRATIONS - MOLES PER KG OF PROPELLANT

NAME		1)	2)	3)
N2	GAS	12.9540	12.9372	12.9117
CO	GAS	12.4218	12.4586	12.4737
H2O	GAS	9.39150	9.43536	9.47855
H2	GAS	7.48557	7.39333	7.27397
CO2	GAS	2.29117	2.24303	2.20788
HF	GAS	$7.75533 \times 10^{-2}$	$7.74548 \times 10^{-2}$	$7.73462 \times 10^{-2}$
Na	GAS	$4.27608 \times 10^{-2}$	$2.32135 \times 10^{-2}$	$1.10324 \times 10^{-2}$
NH3	GAS	$1.71762 \times 10^{-2}$	$4.29731 \times 10^{-2}$	$8.02867 \times 10^{-2}$
AlOF	GAS	$6.99574 \times 10^{-3}$	$7.07163 \times 10^{-3}$	$7.15665 \times 10^{-3}$
AlOH	GAS	$6.07844 \times 10^{-3}$	$5.98729 \times 10^{-3}$	$5.88538 \times 10^{-3}$
HCN	GAS	$4.90063 \times 10^{-3}$	$1.30197 \times 10^{-2}$	$2.58644 \times 10^{-2}$
NO	GAS	$1.48782 \times 10^{-3}$	$9.63007 \times 10^{-4}$	$7.24108 \times 10^{-4}$
AlF	GAS	$1.18772 \times 10^{-3}$	$1.21010 \times 10^{-3}$	$1.22971 \times 10^{-3}$
CH4	GAS	$4.44011 \times 10^{-4}$	$2.46856 \times 10^{-3}$	$7.63790 \times 10^{-3}$
NaO	GAS	$1.10164 \times 10^{-4}$	$6.03275 \times 10^{-5}$	$2.90332 \times 10^{-5}$
O2	GAS	$2.07846 \times 10^{-5}$	$8.32298 \times 10^{-6}$	$4.48209 \times 10^{-6}$
Al	GAS	$2.06167 \times 10^{-5}$	$1.34127 \times 10^{-5}$	$1.00395 \times 10^{-5}$
A2O2	GAS	$3.59719 \times 10^{-6}$	$3.58280 \times 10^{-6}$	$3.56650 \times 10^{-6}$
HNO	GAS	$1.00311 \times 10^{-5}$	$1.04868 \times 10^{-5}$	$1.10040 \times 10^{-5}$
OH	GAS	$1.23971 \times 10^{-2}$	$7.93021 \times 10^{-3}$	$5.87177 \times 10^{-3}$
CH3	GAS	$5.46022 \times 10^{-5}$	$2.15490 \times 10^{-4}$	$5.47522 \times 10^{-4}$
H	GAS	$3.73025 \times 10^{-2}$	$2.38565 \times 10^{-2}$	$1.75935 \times 10^{-2}$
O	GAS	$4.04766 \times 10^{-5}$	$1.70188 \times 10^{-5}$	$9.58520 \times 10^{-6}$
CHO	GAS	$1.37423 \times 10^{-3}$	$2.30258 \times 10^{-3}$	$3.33872 \times 10^{-3}$
CN	GAS	$2.75629 \times 10^{-6}$	$4.94078 \times 10^{-6}$	$7.66189 \times 10^{-6}$
AlO2	GAS	0.0	0.0	0.0
F	GAS	$1.56398 \times 10^{-6}$	$1.03957 \times 10^{-6}$	$7.99428 \times 10^{-7}$
C(S)	SOLID	0.0	0.0	0.0
Na2S	SOLID	0.0	$1.95954 \times 10^{-2}$	$3.18077 \times 10^{-2}$
Na2S	LIQUID	0.0	0.0	0.0
TOTAL GAS (MOLES/KG)		44.7539	44.6763	44.5904
DELTA Q (J/G)		-3093.0	-3093.2	-3095.1

## \*\*\* PROPELLANT MNF2P/S \*\*\*

## INGREDIENT AND FORMULATION INFORMATION

NAME	WT %	MOLE %	$\Delta H$ (CAL/MOL)	EMPIRICAL FORMULA
NC2	16.140	0.009	$-0.1715 \times 10^9$	C H O N 6000 7646 9708 2354
NG	20.540	13.737	$-0.8860 \times 10^5$	C H O N 3 5 9 3
NQ	53.760	78.457	$-0.2210 \times 10^5$	CH O N 4 2 4
EC	7.270	4.114	$-0.2510 \times 10^5$	C H ON 17 20 2
KS	1.990	1.734	$-0.3427 \times 10^6$	K SO 2 4
AC	0.100	0.261	$-0.5927 \times 10^5$	C H O 3 6
H2O	0.200	1.686	$-0.6832 \times 10^5$	H O 2

ENERGY OF FORMATION: -1473.2 JOULES/GRAM

## ELEMENTAL COMPOSITION (MOLE %)

C	15.750
H	34.655
O	24.551
N	24.710
K	0.223
S	0.111

## \* \* SUMMARY OF PROPELLANT GAS THERMODYNAMIC PROPERTIES \* \*

	L.D. G/CM <sup>3</sup>	TEMP K	PRESSURE MPA	IMPETUS J/G	MOL WT	CO-VOL CM <sup>3</sup> /G	I.B. GAMMA	CP J/MOL
1)	0.10	2365	104.21	919.44	21.38	1.176	1.2639	40.35
2)	0.20	2374	237.26	920.00	21.45	1.122	1.2674	40.94
3)	0.30	2388	405.31	920.44	21.56	1.062	1.2735	41.75
	L.D. G/CM <sup>3</sup>	TEMP K	PRESSURE PSIA	IMPETUS FT-LB/LB	MOL WT	CO-VOL IN <sup>3</sup> /LB	I.B. GAMMA	CP CAL/MOL
1)	0.10	2365	15115.1	307653.8	21.38	32.551	1.2639	9.645
2)	0.20	2374	34411.1	307839.7	21.45	31.048	1.2674	9.785
3)	0.30	2388	58785.3	307986.1	21.56	29.396	1.2735	9.979

## \*\*\* PROPELLANT MNF2P/S \*\*\*

PREDICTED COMBUSTION PRODUCTS  
 CONSTITUENT CONCENTRATIONS - MOLES PER KG OF PROPELLANT

NAME		1)	2)	3)
CO	GAS	14.3350	14.3074	14.2166
N2	GAS	12.6447	12.6089	12.5590
H2	GAS	10.3786	10.1581	9.80544
H2O	GAS	7.27890	7.34910	7.44182
CO2	GAS	1.72900	1.69324	1.68233
COS	GAS	$6.71075 \times 10^{-2}$	$8.27617 \times 10^{-2}$	$9.15172 \times 10^{-2}$
NH3	GAS	$3.60282 \times 10^{-2}$	$8.99731 \times 10^{-2}$	$1.64355 \times 10^{-1}$
KOH	GAS	$3.09847 \times 10^{-2}$	$4.46194 \times 10^{-2}$	$5.65424 \times 10^{-2}$
HCN	GAS	$1.03864 \times 10^{-2}$	$2.77068 \times 10^{-2}$	$5.41120 \times 10^{-2}$
CH4	GAS	$6.71284 \times 10^{-3}$	$3.60234 \times 10^{-2}$	$1.01788 \times 10^{-1}$
NO	GAS	$7.19181 \times 10^{-5}$	$4.88090 \times 10^{-5}$	$4.02728 \times 10^{-5}$
O2	GAS	$1.82711 \times 10^{-7}$	$7.84632 \times 10^{-8}$	$4.88395 \times 10^{-8}$
K	GAS	$1.97416 \times 10^{-1}$	$1.83778 \times 10^{-1}$	$1.71864 \times 10^{-1}$
HNO	GAS	$5.05783 \times 10^{-7}$	$5.56098 \times 10^{-7}$	$6.39564 \times 10^{-7}$
S	GAS	$4.31710 \times 10^{-4}$	$2.12256 \times 10^{-4}$	$1.28634 \times 10^{-4}$
OH	GAS	$1.04841 \times 10^{-3}$	$6.95388 \times 10^{-4}$	$5.53478 \times 10^{-4}$
KO	GAS	$1.16350 \times 10^{-6}$	$1.15304 \times 10^{-6}$	$1.20341 \times 10^{-6}$
SO	GAS	$1.46422 \times 10^{-3}$	$7.18264 \times 10^{-4}$	$4.40650 \times 10^{-4}$
HS	GAS	$3.04972 \times 10^{-2}$	$2.24718 \times 10^{-2}$	$1.73215 \times 10^{-2}$
CH3	GAS	$1.47447 \times 10^{-4}$	$5.79689 \times 10^{-4}$	$1.42470 \times 10^{-3}$
H	GAS	$8.86310 \times 10^{-3}$	$5.79471 \times 10^{-3}$	$4.44326 \times 10^{-3}$
O	GAS	$6.27441 \times 10^{-7}$	$2.81954 \times 10^{-7}$	$1.80535 \times 10^{-7}$
CHO	GAS	$5.67563 \times 10^{-4}$	$9.72068 \times 10^{-4}$	$1.45174 \times 10^{-3}$
KSO4	GAS	$2.22753 \times 10^{-9}$	$5.41020 \times 10^{-9}$	$9.49571 \times 10^{-9}$
CN	GAS	$6.07336 \times 10^{-7}$	$1.13518 \times 10^{-6}$	$1.85818 \times 10^{-6}$
S2	GAS	$7.35010 \times 10^{-3}$	$4.01759 \times 10^{-3}$	$2.39784 \times 10^{-3}$
SO3	GAS	$6.37549 \times 10^{-9}$	$3.21233 \times 10^{-9}$	$2.11714 \times 10^{-9}$
C(S)	SOLID	0.0	0.0	0.0
KSO\$	SOLID	0.0	0.0	0.0
KSO\$	LIQUID	0.0	0.0	0.0
TOTAL GAS (MOLES/KG)		46.7653	46.6171	46.3735
DELTA Q (J/G)		-2552.0	-2557.2	-2573.8



## \*\*\* PROPELLANT MNLF2P \*\*\*

## INGREDIENT AND FORMULATION INFORMATION

NAME	WT %	MOLE %	$\Delta H$ (CAL/MOL)	EMPIRICAL FORMULA
NC2	16.250	0.009	$-0.1715 \times 10^9$	C H O N 6000 7646 9708 2354
NG	16.250	10.940	$-0.8860 \times 10^5$	C H O N 3 5 9 3
NQ	53.700	78.886	$-0.2210 \times 10^5$	CH O N 4 2 4
EC	7.350	4.187	$-0.2510 \times 10^5$	C H ON 17 20 2
KS	1.950	1.711	$-0.3427 \times 10^6$	K SO 2 4
DB	4.200	2.307	$-0.2014 \times 10^6$	C H O 16 22 4
AC	0.100	0.263	$-0.5927 \times 10^5$	C H O 3 6
H2O	0.200	1.697	$-0.6832 \times 10^5$	H O 2

ENERGY OF FORMATION: -1529.8 JOULES/GRAM

## ELEMENTAL COMPOSITION (MOLE %)

C	17.167
H	36.086
O	22.899
N	23.529
K	0.213
S	0.106

## \* \* SUMMARY OF PROPELLANT GAS THERMODYNAMIC PROPERTIES \* \*

	L.D. G/CM <sup>3</sup>	TEMP K	PRESSURE MPA	IMPETUS J/G	MOL WT	CO-VOL CM <sup>3</sup> /G	I.B. GAMMA	CP J/MOL
1)	0.10	1964	91.68	803.06	20.33	1.239	1.2833	38.33
2)	0.20	2021	212.07	811.37	20.70	1.174	1.2807	39.74
3)	0.30	2077	367.61	818.51	21.09	1.106	1.2817	41.31
	L.D. G/CM <sup>3</sup>	TEMP K	PRESSURE PSIA	IMPETUS FT-LB/LB	MOL WT	CO-VOL IN <sup>3</sup> /LB	I.B. GAMMA	CP CAL/MOL
1)	0.10	1964	13296.5	268712.0	20.33	34.288	1.2833	9.161
2)	0.20	2021	30758.8	271490.4	20.70	32.482	1.2807	9.498
3)	0.30	2077	53317.9	273881.0	21.09	30.625	1.2817	9.874

## \*\*\* PROPELLANT MNLF2P \*\*\*

PREDICTED COMBUSTION PRODUCTS  
 CONSTITUENT CONCENTRATIONS - MOLES PER KG OF PROPELLANT

NAME		1)	2)	3)
CO	GAS	16.4442	15.9828	15.4983
H2	GAS	13.5544	12.3038	11.0531
N2	GAS	12.3288	12.2679	12.2006
H2O	GAS	4.91361	5.25704	5.58631
CO2	GAS	1.31341	1.36492	1.43649
CH4	GAS	$1.86695 \times 10^{-1}$	$5.61218 \times 10^{-1}$	$9.35832 \times 10^{-1}$
COS	GAS	$9.79588 \times 10^{-2}$	$1.02369 \times 10^{-1}$	$1.04261 \times 10^{-1}$
NH3	GAS	$8.09889 \times 10^{-2}$	$1.72758 \times 10^{-1}$	$2.71193 \times 10^{-1}$
HCN	GAS	$2.30323 \times 10^{-2}$	$5.28603 \times 10^{-2}$	$8.92407 \times 10^{-2}$
KOH	GAS	$1.56032 \times 10^{-2}$	$2.57954 \times 10^{-2}$	$3.66099 \times 10^{-2}$
NO	GAS	$1.14607 \times 10^{-6}$	$1.45706 \times 10^{-6}$	$2.08888 \times 10^{-6}$
O2	GAS	$3.02453 \times 10^{-10}$	$3.46445 \times 10^{-10}$	$5.12646 \times 10^{-10}$
K	GAS	$2.08207 \times 10^{-1}$	$1.98012 \times 10^{-1}$	$1.87208 \times 10^{-1}$
HNO	GAS	$7.90883 \times 10^{-9}$	$1.60744 \times 10^{-8}$	$3.15460 \times 10^{-8}$
S	GAS	$2.82960 \times 10^{-5}$	$1.85437 \times 10^{-5}$	$1.54097 \times 10^{-5}$
OH	GAS	$3.32163 \times 10^{-5}$	$3.66871 \times 10^{-5}$	$4.56102 \times 10^{-5}$
KO	GAS	$2.46017 \times 10^{-8}$	$4.52499 \times 10^{-8}$	$8.06237 \times 10^{-8}$
SO	GAS	$6.40614 \times 10^{-5}$	$4.55565 \times 10^{-5}$	$4.14577 \times 10^{-5}$
HS	GAS	$8.87212 \times 10^{-3}$	$6.90279 \times 10^{-3}$	$5.93155 \times 10^{-3}$
CH3	GAS	$3.81004 \times 10^{-4}$	$1.21013 \times 10^{-3}$	$2.41668 \times 10^{-3}$
H	GAS	$1.04421 \times 10^{-3}$	$9.13997 \times 10^{-4}$	$9.00811 \times 10^{-4}$
O	GAS	$1.96821 \times 10^{-9}$	$2.09636 \times 10^{-9}$	$2.86223 \times 10^{-9}$
CHO	GAS	$1.40540 \times 10^{-4}$	$2.90006 \times 10^{-4}$	$5.05456 \times 10^{-4}$
KSO4	GAS	$3.60162 \times 10^{-10}$	$1.20228 \times 10^{-9}$	$2.98197 \times 10^{-9}$
CN	GAS	$5.80982 \times 10^{-8}$	$1.49234 \times 10^{-7}$	$3.18499 \times 10^{-7}$
S2	GAS	$2.49086 \times 10^{-3}$	$1.28426 \times 10^{-3}$	$8.29758 \times 10^{-4}$
SO3	GAS	$2.31598 \times 10^{-11}$	$2.55350 \times 10^{-11}$	$3.61095 \times 10^{-11}$
C(S)	SOLID	0.0	0.0	0.0
KSO\$	SOLID	0.0	0.0	0.0
KSO\$	LIQUID	0.0	0.0	0.0
TOTAL GAS (MOLES/KG)		49.1800	48.3003	47.4098
DELTA Q (J/G)		-2010.3	-2094.8	-2181.5

## \*\*\* PROPELLANT MNQF \*\*\*

## INGREDIENT AND FORMULATION INFORMATION

NAME	WT %	MOLE %	$\Delta H$ (CAL/MOL)	EMPIRICAL FORMULA
NC2	20.850	0.012	$-0.1715 \times 10^9$	C H O N 6000 7646 9708 2354
NG	20.850	14.244	$-0.8860 \times 10^5$	C H O N 3 5 9 3
NQ	54.520	81.276	$-0.2210 \times 10^5$	CH O N 4 2 4
EC	2.980	1.723	$-0.2510 \times 10^5$	C H ON 17 20 2
CRY	0.300	0.222	$-0.7890 \times 10^6$	Na AlF 3 6
AC	0.300	0.801	$-0.5927 \times 10^5$	C H O 3 6
H2O	0.200	1.722	$-0.6832 \times 10^5$	H O 2

ENERGY OF FORMATION: -1486.3 JOULES/GRAM

## ELEMENTAL COMPOSITION (MOLE %)

C	14.497
H	33.766
O	26.194
N	25.402
Na	0.042
Al	0.014
F	0.085

## \* \* SUMMARY OF PROPELLANT GAS THERMODYNAMIC PROPERTIES \* \*

	L.D. G/CM <sup>3</sup>	TEMP K	PRESSURE MPA	IMPETUS J/G	MOL WT	CO-VOL CM <sup>3</sup> /G	I.B. GAMMA	CP J/MOL
1)	0.10	2742	115.15	1021.16	22.32	1.131	1.2459	42.61
2)	0.20	2746	260.63	1020.78	22.34	1.083	1.2495	43.04
3)	0.30	2749	442.85	1020.12	22.37	1.029	1.2560	43.63
	L.D. G/CM <sup>3</sup>	TEMP K	PRESSURE PSIA	IMPETUS FT-LB/LB	MOL WT	CO-VOL IN <sup>3</sup> /LB	I.B. GAMMA	CP CAL/MOL
1)	0.10	2742	16701.8	341689.1	22.32	31.300	1.2459	10.183
2)	0.20	2746	37801.8	341562.1	22.34	29.972	1.2495	10.288
3)	0.30	2749	64230.4	341338.7	22.38	28.495	1.2560	10.428

## \*\*\* PROPELLANT MNQF \*\*\*

PREDICTED COMBUSTION PRODUCTS  
 CONSTITUENT CONCENTRATIONS - MOLES PER KG OF PROPELLANT

NAME		1)	2)	3)
N2	GAS	12.8697	12.8528	12.8272
CO	GAS	12.3744	12.4123	12.4286
H2O	GAS	9.52025	9.56552	9.60910
H2	GAS	7.50782	7.41342	7.29207
CO2	GAS	2.32178	2.27265	2.23644
HF	GAS	$7.74581 \times 10^{-2}$	$7.73633 \times 10^{-2}$	$7.72577 \times 10^{-2}$
Na	GAS	$4.27688 \times 10^{-2}$	$2.41343 \times 10^{-2}$	$1.14801 \times 10^{-2}$
NH3	GAS	$1.73856 \times 10^{-2}$	$4.35048 \times 10^{-2}$	$8.12940 \times 10^{-2}$
AlOF	GAS	$7.12041 \times 10^{-3}$	$7.19255 \times 10^{-3}$	$7.27455 \times 10^{-3}$
AlOH	GAS	$5.98533 \times 10^{-3}$	$5.89716 \times 10^{-3}$	$5.79785 \times 10^{-3}$
HCN	GAS	$4.79081 \times 10^{-3}$	$1.27395 \times 10^{-2}$	$2.53286 \times 10^{-2}$
NO	GAS	$1.34468 \times 10^{-3}$	$8.72215 \times 10^{-4}$	$6.56798 \times 10^{-4}$
AlF	GAS	$1.15845 \times 10^{-3}$	$1.18081 \times 10^{-3}$	$1.20049 \times 10^{-3}$
CH4	GAS	$4.66436 \times 10^{-4}$	$2.59034 \times 10^{-3}$	$8.00849 \times 10^{-3}$
NaO	GAS	$1.03302 \times 10^{-4}$	$5.88791 \times 10^{-5}$	$2.83844 \times 10^{-5}$
Al	GAS	$1.85055 \times 10^{-5}$	$1.20709 \times 10^{-5}$	$9.05486 \times 10^{-6}$
O2	GAS	$1.81059 \times 10^{-5}$	$7.27099 \times 10^{-6}$	$3.92296 \times 10^{-6}$
A2O2	GAS	$3.51403 \times 10^{-6}$	$3.50162 \times 10^{-6}$	$3.48683 \times 10^{-6}$
HNO	GAS	$9.02501 \times 10^{-6}$	$9.45482 \times 10^{-6}$	$9.93500 \times 10^{-6}$
OH	GAS	$1.14522 \times 10^{-2}$	$7.33752 \times 10^{-3}$	$5.43876 \times 10^{-3}$
CH3	GAS	$5.34518 \times 10^{-5}$	$2.11033 \times 10^{-4}$	$5.36399 \times 10^{-4}$
H	GAS	$3.47949 \times 10^{-2}$	$2.22874 \times 10^{-2}$	$1.64560 \times 10^{-2}$
O	GAS	$3.48745 \times 10^{-5}$	$1.47113 \times 10^{-5}$	$8.30518 \times 10^{-6}$
CHO	GAS	$1.29910 \times 10^{-3}$	$2.17925 \times 10^{-3}$	$3.16255 \times 10^{-3}$
CN	GAS	$2.45045 \times 10^{-6}$	$4.40446 \times 10^{-6}$	$6.84493 \times 10^{-6}$
AlO2	GAS	0.0	0.0	0.0
F	GAS	$1.38949 \times 10^{-6}$	$9.25836 \times 10^{-7}$	$7.13273 \times 10^{-7}$
C(S)	SOLID	0.0	0.0	0.0
Na2S	SOLID	0.0	$1.86759 \times 10^{-2}$	$3.13607 \times 10^{-2}$
Na2S	LIQUID	0.0	0.0	0.0
TOTAL GAS (MOLES/KG)		44.8003	44.7244	44.6373
DELTA Q (J/G)		-3069.2	-3069.3	-3070.9

## \*\*\* PROPELLANT N (N/S) \*\*\*

## INGREDIENT AND FORMULATION INFORMATION

NAME	WT %	MOLE %	$\Delta H$ (CAL/MOL)	EMPIRICAL FORMULA
NC5	18.910	0.010	$-0.1646 \times 10^9$	C H O N 6000 7364 10271 2636
NG	18.610	12.690	$-0.8860 \times 10^5$	C H O N 3 5 9 3
NQ	54.720	81.421	$-0.2210 \times 10^5$	CH O N 4 2 4
EC	7.260	4.189	$-0.2510 \times 10^5$	C H ON 17 20 2
KS	0.300	0.267	$-0.3427 \times 10^6$	K SO 2 4
AC	0.050	0.133	$-0.5927 \times 10^5$	C H O 3 6
H2O	0.150	1.289	$-0.6832 \times 10^5$	H O 2

ENERGY OF FORMATION: -1333.1 JOULES/GRAM

## ELEMENTAL COMPOSITION (MOLE %)

C	15.875
H	34.611
O	24.458
N	25.007
K	0.033
S	0.017

## \* \* SUMMARY OF PROPELLANT GAS THERMODYNAMIC PROPERTIES \* \*

	L.D. G/CM <sup>3</sup>	TEMP K	PRESSURE MPA	IMPETUS J/G	MOL WT	CO-VOL CM <sup>3</sup> /G	I.B. GAMMA	CP J/MOL
1)	0.10	2440	108.56	956.13	21.22	1.191	1.2626	40.45
2)	0.20	2447	247.49	956.30	21.27	1.135	1.2660	41.00
3)	0.30	2459	423.31	956.16	21.38	1.074	1.2722	41.78
	L.D. G/CM <sup>3</sup>	TEMP K	PRESSURE PSIA	IMPETUS FT-LB/LB	MOL WT	CO-VOL IN <sup>3</sup> /LB	I.B. GAMMA	CP CAL/MOL
1)	0.10	2440	15744.7	319926.1	21.22	32.964	1.2626	9.667
2)	0.20	2447	35895.4	319987.1	21.28	31.426	1.2660	9.800
3)	0.30	2459	61396.1	319938.4	21.38	29.734	1.2722	9.986

## \*\*\* PROPELLANT N (N/S) \*\*\*

PREDICTED COMBUSTION PRODUCTS  
 CONSTITUENT CONCENTRATIONS - MOLES PER KG OF PROPELLANT

NAME		1)	2)	3)
CO	GAS	14.6922	14.6761	14.5949
N2	GAS	12.8804	12.8443	12.7925
H2	GAS	10.5706	10.3600	10.0264
H2O	GAS	7.20623	7.27971	7.37278
CO2	GAS	1.66253	1.63195	1.62440
NH3	GAS	$3.53447 \times 10^{-2}$	$8.86371 \times 10^{-2}$	$1.62949 \times 10^{-1}$
HCN	GAS	$1.14616 \times 10^{-2}$	$3.06029 \times 10^{-2}$	$5.99443 \times 10^{-2}$
COS	GAS	$1.04504 \times 10^{-2}$	$1.25828 \times 10^{-2}$	$1.37906 \times 10^{-2}$
CH4	GAS	$5.51062 \times 10^{-3}$	$3.00189 \times 10^{-2}$	$8.66979 \times 10^{-2}$
KOH	GAS	$4.74480 \times 10^{-3}$	$6.83652 \times 10^{-3}$	$8.66035 \times 10^{-3}$
NO	GAS	$1.18854 \times 10^{-4}$	$7.93119 \times 10^{-5}$	$6.39657 \times 10^{-5}$
O2	GAS	$3.70439 \times 10^{-7}$	$1.55178 \times 10^{-7}$	$9.33226 \times 10^{-8}$
K	GAS	$2.96878 \times 10^{-2}$	$2.75964 \times 10^{-2}$	$2.57727 \times 10^{-2}$
HNO	GAS	$8.67290 \times 10^{-7}$	$9.39242 \times 10^{-7}$	$1.05809 \times 10^{-6}$
S	GAS	$1.01702 \times 10^{-4}$	$4.79269 \times 10^{-5}$	$2.81352 \times 10^{-5}$
OH	GAS	$1.59628 \times 10^{-3}$	$1.04472 \times 10^{-3}$	$8.16670 \times 10^{-4}$
KO	GAS	$2.78246 \times 10^{-7}$	$2.71422 \times 10^{-7}$	$2.77237 \times 10^{-7}$
SO	GAS	$3.22828 \times 10^{-4}$	$1.52183 \times 10^{-4}$	$9.05885 \times 10^{-5}$
HS	GAS	$5.92056 \times 10^{-3}$	$4.21597 \times 10^{-3}$	$3.18184 \times 10^{-3}$
CH3	GAS	$1.67930 \times 10^{-4}$	$6.63042 \times 10^{-4}$	$1.64181 \times 10^{-3}$
H	GAS	$1.25836 \times 10^{-2}$	$8.13241 \times 10^{-3}$	$6.14900 \times 10^{-3}$
O	GAS	$1.31319 \times 10^{-6}$	$5.75208 \times 10^{-7}$	$3.56035 \times 10^{-7}$
CHO	GAS	$7.59315 \times 10^{-4}$	$1.29456 \times 10^{-3}$	$1.92215 \times 10^{-3}$
KSO4	GAS	$6.44012 \times 10^{-12}$	$1.53520 \times 10^{-11}$	$2.67136 \times 10^{-11}$
CN	GAS	$1.04337 \times 10^{-6}$	$1.92478 \times 10^{-6}$	$3.10183 \times 10^{-6}$
S2	GAS	$2.11765 \times 10^{-4}$	$1.08855 \times 10^{-4}$	$6.27766 \times 10^{-5}$
SO3	GAS	$1.59138 \times 10^{-9}$	$7.68315 \times 10^{-10}$	$4.87815 \times 10^{-10}$
C(S)	SOLID	0.0	0.0	0.0
KSO\$	SOLID	0.0	0.0	0.0
KSO\$	LIQUID	0.0	0.0	0.0
TOTAL GAS (MOLES/KG)		47.1309	47.0041	46.7828
DELTA Q (J/G)		-2686.9	-2696.1	-2714.7

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APPENDIX III

PROPELLANTS OF AMERICAN ORIGIN

This appendix presents calculated thermodynamic data for the following propellant formulations:

BS-NACO(D)	5 inch/54 calibre naval gun
M1	M3A1 and M4A2 155 mm howitzer charges
M6	M119 155 mm howitzer charge
M9	81 mm mortar
M30	105 mm tank gun
M30A1	M203 155 mm howitzer charge
M30A2	
RGP-150a	Experimental Nitramine propellant (HMX-based)
RGP-150b	Experimental Nitramine propellant (RDX-based)

(See page 7 for table of ingredient abbreviations)



## \*\*\* PROPELLANT BS-NACO (D) \*\*\*

## INGREDIENT AND FORMULATION INFORMATION

NAME	WT %	MOLE %	$\Delta H$ (CAL/MOL)	EMPIRICAL FORMULA
NC1	91.270	0.230	$-0.1738 \times 10^9$	C H O N 6000 7739 9521 2261
KS	0.970	3.700	$-0.347 \times 10^6$	K SO 2 4
EC	0.970	2.403	$-0.2510 \times 10^5$	C H ON 17 20 2
PBC	0.970	2.413	$-0.1673 \times 10^6$	PbCO 3
NBUS	2.910	5.679	$-0.2290 \times 10^6$	C H O 22 44 2
H2O	1.940	71.580	$-0.6832 \times 10^5$	H O 2
AL	0.970	13.996	$-0.6642 \times 10^5$	C H O 2 6

ENERGY OF FORMATION: -3072.1 JOULES/GRAM

## ELEMENTAL COMPOSITION (MOLE %)

C	23.418
H	34.247
O	34.337
N	7.797
K	0.110
S	0.055
Pb	0.036

## \* \* SUMMARY OF PROPELLANT GAS THERMODYNAMIC PROPERTIES \* \*

	L.D. G/CM <sup>3</sup>	TEMP K	PRESSURE MPA	IMPETUS J/G	MOL WT	CO-VOL CM <sup>3</sup> /G	I.B. GAMMA	CP J/MOL
1)	0.10	2235.	94.24	837.51	22.18	1.111	1.2601	41.19
2)	0.20	2247.	213.40	839.53	22.25	1.065	1.2648	41.82
3)	0.30	2267.	363.07	842.02	22.38	1.014	1.2709	42.68

	L.D. G/CM <sup>3</sup>	TEMP K	PRESSURE PSIA	IMPETUS FT-LB/LB	MOL WT	CO-VOL IN <sup>3</sup> /LB	I.B. GAMMA	CP CAL/MOL
1)	0.10	2235.	13668.1	280237.2	22.18	30.763	1.2601	9.844
2)	0.20	2247.	30951.5	280913.3	22.25	29.488	1.2648	9.994
3)	0.30	2267.	52659.5	281747.8	22.38	28.062	1.2709	10.201

## \*\*\* PROPELLANT BS-NACO (D) \*\*\*

PREDICTED COMBUSTION PRODUCTS  
 CONSTITUENT CONCENTRATIONS - MOLES PER KG OF PROPELLANT

NAME		1)	2)	3)
CO	GAS	20.4722	20.4527	20.3260
H2	GAS	9.38067	9.14209	8.77359
H2O	GAS	7.88373	7.97865	8.08116
N2	GAS	3.93374	3.91457	3.88805
CO2	GAS	3.17034	3.12733	3.13540
COS	GAS	$4.45096 \times 10^{-2}$	$4.88214 \times 10^{-2}$	$5.08101 \times 10^{-2}$
Pb	GAS	$3.59283 \times 10^{-2}$	$3.57460 \times 10^{-2}$	$3.55009 \times 10^{-2}$
NH3	GAS	$1.92077 \times 10^{-2}$	$4.72493 \times 10^{-2}$	$8.43174 \times 10^{-2}$
KOH	GAS	$1.58555 \times 10^{-2}$	$2.26652 \times 10^{-2}$	$2.85533 \times 10^{-2}$
CH4	GAS	$1.12893 \times 10^{-2}$	$5.86182 \times 10^{-2}$	$1.58203 \times 10^{-1}$
HCN	GAS	$6.26757 \times 10^{-3}$	$1.67285 \times 10^{-2}$	$3.27117 \times 10^{-2}$
PbO	GAS	$2.44971 \times 10^{-4}$	$2.53048 \times 10^{-4}$	$2.70908 \times 10^{-4}$
Pb2	GAS	$6.38867 \times 10^{-5}$	$1.51319 \times 10^{-4}$	$2.64984 \times 10^{-4}$
NO	GAS	$1.78998 \times 10^{-5}$	$1.26030 \times 10^{-5}$	$1.10246 \times 10^{-5}$
O2	GAS	$6.17833 \times 10^{-8}$	$2.81830 \times 10^{-8}$	$1.93052 \times 10^{-8}$
K	GAS	$9.54759 \times 10^{-2}$	$8.86680 \times 10^{-2}$	$8.27802 \times 10^{-2}$
HNO	GAS	$1.13238 \times 10^{-7}$	$1.28161 \times 10^{-7}$	$1.55111 \times 10^{-7}$
S	GAS	$8.74977 \times 10^{-5}$	$3.95729 \times 10^{-5}$	$2.37422 \times 10^{-5}$
OH	GAS	$5.19153 \times 10^{-4}$	$3.55278 \times 10^{-4}$	$2.97509 \times 10^{-4}$
KO	GAS	$2.64808 \times 10^{-7}$	$2.70201 \times 10^{-7}$	$2.97202 \times 10^{-7}$
SO	GAS	$3.80917 \times 10^{-4}$	$1.71257 \times 10^{-4}$	$1.03462 \times 10^{-4}$
HS	GAS	$8.60927 \times 10^{-3}$	$5.72230 \times 10^{-3}$	$4.23848 \times 10^{-3}$
CH3	GAS	$1.37712 \times 10^{-4}$	$5.36410 \times 10^{-4}$	$1.30974 \times 10^{-3}$
H	GAS	$4.42879 \times 10^{-3}$	$2.97104 \times 10^{-3}$	$2.37258 \times 10^{-3}$
O	GAS	$1.76222 \times 10^{-7}$	$8.40109 \times 10^{-8}$	$5.91242 \times 10^{-8}$
CHO	GAS	$4.73561 \times 10^{-4}$	$8.24045 \times 10^{-4}$	$1.26842 \times 10^{-3}$
KSO4	GAS	$5.50840 \times 10^{-10}$	$1.15702 \times 10^{-9}$	$1.84923 \times 10^{-9}$
CN	GAS	$1.63303 \times 10^{-7}$	$3.14029 \times 10^{-7}$	$5.41081 \times 10^{-7}$
S2	GAS	$1.03957 \times 10^{-3}$	$4.56121 \times 10^{-4}$	$2.45567 \times 10^{-4}$
TOTAL GAS (MOLES/KG)		45.0853	44.9453	44.6875
DELTA Q (J/G)		-2345.5	-2354.4	-2377.6

## \*\*\* PROPELLANT M1 \*\*\*

## INGREDIENT AND FORMULATION INFORMATION

NAME	WT %	MOLE %	$\Delta H$ (CAL/MOL)	EMPIRICAL FORMULA
NC5	83.100	0.244	$-0.1646 \times 10^9$	C H O N 6000 7364 10271 2636
DN	9.780	44.228	$-0.1710 \times 10^5$	C H O N 7 6 4 2
DB	4.880	14.440	$-0.2014 \times 10^6$	C H O 16 22 4
DP	0.990	4.819	$0.3107 \times 10^5$	C H N 12 11
H2O	0.500	22.860	$-0.6832 \times 10^5$	H O 2
AL	0.750	13.409	$-0.6642 \times 10^5$	C H O 2 6

ENERGY OF FORMATION: -2342.3 JOULES/GRAM

## ELEMENTAL COMPOSITION (MOLE %)

C	25.600
H	31.356
O	34.022
N	9.023

## \* \* SUMMARY OF PROPELLANT GAS THERMODYNAMIC PROPERTIES \* \*

	L.D. G/CM <sup>3</sup>	TEMP K	PRESSURE MPA	IMPETUS J/G	MOL WT	CO-VOL CM <sup>3</sup> /G	I.B. GAMMA	CP J/MOL
1)	0.10	2432	103.70	916.04	22.07	1.165	1.2629	40.43
2)	0.20	2440	235.71	916.62	22.13	1.111	1.2663	40.97
3)	0.30	2454	402.12	917.31	22.24	1.052	1.2721	41.75
	L.D. G/CM <sup>3</sup>	TEMP K	PRESSURE PSIA	IMPETUS FT-LB/LB	MOL WT	CO-VOL IN <sup>3</sup> /LB	I.B. GAMMA	CP CAL/MOL
1)	0.10	2432	15040.4	306523.6	22.07	32.240	1.2629	9.663
2)	0.20	2440	34187.1	306709.8	22.13	30.742	1.2663	9.792
3)	0.30	2454	58323.1	306938.5	22.24	29.114	1.2721	9.979

## \*\*\* PROPELLANT M1 \*\*\*

PREDICTED COMBUSTION PRODUCTS  
 CONSTITUENT CONCENTRATIONS - MOLES PER KG OF PROPELLANT

NAME		1)	2)	3)
CO	GAS	22.9309	22.8953	22.7603
H2	GAS	9.51381	9.32622	9.01919
H2O	GAS	5.95693	6.02850	6.10971
N2	GAS	4.45310	4.43112	4.39973
CO2	GAS	2.40052	2.38254	2.40962
NH3	GAS	$1.77155 \times 10^{-2}$	$4.39355 \times 10^{-2}$	$7.95213 \times 10^{-2}$
HCN	GAS	$1.07827 \times 10^{-2}$	$2.87007 \times 10^{-2}$	$5.63322 \times 10^{-2}$
NO	GAS	$6.08842 \times 10^{-5}$	$4.08845 \times 10^{-5}$	$3.35152 \times 10^{-5}$
CH4	GAS	$7.76995 \times 10^{-3}$	$4.21279 \times 10^{-2}$	$1.20868 \times 10^{-1}$
O2	GAS	$2.90367 \times 10^{-7}$	$1.23884 \times 10^{-7}$	$7.72302 \times 10^{-8}$
HNO	GAS	$4.18323 \times 10^{-7}$	$4.53865 \times 10^{-7}$	$5.17617 \times 10^{-7}$
OH	GAS	$1.33164 \times 10^{-3}$	$8.79442 \times 10^{-4}$	$7.00486 \times 10^{-4}$
CH3	GAS	$2.40776 \times 10^{-4}$	$9.48865 \times 10^{-4}$	$2.36124 \times 10^{-3}$
H	GAS	$1.15505 \times 10^{-2}$	$7.51386 \times 10^{-3}$	$5.76308 \times 10^{-3}$
O	GAS	$1.11873 \times 10^{-6}$	$4.97526 \times 10^{-7}$	$3.18419 \times 10^{-7}$
CHO	GAS	$1.09267 \times 10^{-3}$	$1.87635 \times 10^{-3}$	$2.84064 \times 10^{-3}$
CN	GAS	$9.87550 \times 10^{-7}$	$1.82624 \times 10^{-6}$	$2.99949 \times 10^{-6}$
C(S)	SOLID	0.0	0.0	0.0
TOTAL GAS (MOLES/KG)		45.3058	45.1897	44.9669
DELTA Q (J/G)		-2576.1	-2587.0	-2610.1

## \*\*\* PROPELLANT M6 \*\*\*

## INGREDIENT AND FORMULATION INFORMATION

NAME	WT %	MOLE %	$\Delta H$ (CAL/MOL)	EMPIRICAL FORMULA
NC5	85.610	0.324	$-0.1646 \times 10^9$	C H O N 6000 7364 10271 2636
DN	9.840	57.472	$-0.1710 \times 10^5$	C H O N 7 6 4 2
DB	2.950	11.274	$-0.2014 \times 10^6$	C H O 16 22 4
DP	1.000	6.286	$0.3107 \times 10^5$	C H N 12 11
H2O	0.300	17.715	$-0.6832 \times 10^5$	H O 2
AL	0.300	6.927	$-0.6642 \times 10^5$	C H O 2 6

ENERGY OF FORMATION: -2286.8 JOULES/GRAM

## ELEMENTAL COMPOSITION (MOLE %)

C	25.288
H	30.209
O	35.073
N	9.430

## \* \* SUMMARY OF PROPELLANT GAS THERMODYNAMIC PROPERTIES \* \*

	L.D. G/CM <sup>3</sup>	TEMP K	PRESSURE MPA	IMPETUS J/G	MOL WT	CO-VOL CM <sup>3</sup> /G	I.B. GAMMA	CP J/MOL
1)	0.10	2644.	108.86	964.70	22.78	1.136	1.2540	41.49
2)	0.20	2649.	246.65	965.26	22.81	1.086	1.2576	41.93
3)	0.30	2655.	419.30	965.43	22.86	1.030	1.2638	42.55

	L.D. G/CM <sup>3</sup>	TEMP K	PRESSURE PSIA	IMPETUS FT-LB/LB	MOL WT	CO-VOL IN <sup>3</sup> /LB	I.B. GAMMA	CP CAL/MOL
1)	0.10	2644.	15788.6	322804.1	22.78	31.455	1.2540	9.915
2)	0.20	2649.	35772.9	322984.3	22.81	30.055	1.2576	10.021
3)	0.30	2655.	60815.0	323041.4	22.86	28.524	1.2638	10.169

\*\*\* PROPELLANT M6 \*\*\*

PREDICTED COMBUSTION PRODUCTS  
CONSTITUENT CONCENTRATIONS - MOLES PER KG OF PROPELLANT

NAME		1)	2)	3)
CO	GAS	21.7792	21.7877	21.7463
H2	GAS	7.95481	7.85488	7.72013
H2O	GAS	6.70511	6.75947	6.80444
N2	GAS	4.57904	4.56400	4.54171
CO2	GAS	2.82287	2.79170	2.79023
NH3	GAS	$1.18878 \times 10^{-2}$	$2.95903 \times 10^{-2}$	$5.47493 \times 10^{-2}$
HCN	GAS	$7.51771 \times 10^{-3}$	$1.99918 \times 10^{-2}$	$3.98937 \times 10^{-2}$
NO	GAS	$3.10577 \times 10^{-4}$	$2.02728 \times 10^{-4}$	$1.54335 \times 10^{-4}$
CH4	GAS	$1.84983 \times 10^{-3}$	$1.02661 \times 10^{-2}$	$3.17341 \times 10^{-2}$
O2	GAS	$3.63808 \times 10^{-6}$	$1.48647 \times 10^{-6}$	$8.24181 \times 10^{-7}$
HNO	GAS	$2.08232 \times 10^{-6}$	$2.19477 \times 10^{-6}$	$2.33124 \times 10^{-6}$
OH	GAS	$4.97934 \times 10^{-3}$	$3.21993 \times 10^{-3}$	$2.42197 \times 10^{-3}$
CH3	GAS	$1.45848 \times 10^{-4}$	$5.77998 \times 10^{-4}$	$1.48314 \times 10^{-3}$
H	GAS	$2.51186 \times 10^{-2}$	$1.61769 \times 10^{-2}$	$1.20613 \times 10^{-2}$
O	GAS	$1.04892 \times 10^{-5}$	$4.49051 \times 10^{-6}$	$2.59952 \times 10^{-6}$
CHO	GAS	$1.80382 \times 10^{-3}$	$3.05716 \times 10^{-3}$	$4.52327 \times 10^{-3}$
CN	GAS	$2.34813 \times 10^{-6}$	$4.25014 \times 10^{-6}$	$6.72186 \times 10^{-6}$
C(S)	SOLID	0.0	0.0	0.0
TOTAL GAS (MOLES/KG)		43.8946	43.8408	43.7498
DELTA Q (J/G)		-2847.7	-2853.0	-2862.3

## \*\*\* PROPELLANT M9 \*\*\*

## INGREDIENT AND FORMULATION INFORMATION

NAME	WT %	MOLE %	$\Delta H$ (CAL/MOL)	EMPIRICAL FORMULA
NC6	57.490	0.097	$-0.1638 \times 10^9$	C H O N 6000 7329 10341 2671
NG	39.920	83.982	$-0.8860 \times 10^5$	C H O N 3 5 9 3
KN	1.490	7.041	$-0.1178 \times 10^6$	KNO 3
EC	0.800	1.424	$-0.2510 \times 10^5$	C H ON 17 20 2
C	0.100	3.981	0.0	C
AC	0.100	0.823	$-0.5927 \times 10^5$	C H O 3 6
H2O	0.100	2.652	$-0.6832 \times 10^5$	H O 2

ENERGY OF FORMATION: -2143.3 JOULES/GRAM

## ELEMENTAL COMPOSITION (MOLE %)

C	19.894
H	26.906
O	41.058
N	11.980
K	0.162

## \* \* SUMMARY OF PROPELLANT GAS THERMODYNAMIC PROPERTIES \* \*

	L.D. G/CM <sup>3</sup>	TEMP K	PRESSURE MPA	IMPETUS J/G	MOL WT	CO-VOL CM <sup>3</sup> /G	I.B. GAMMA	CP J/MOL
1)	0.10	3762	127.38	1148.98	27.22	0.979	1.2050	49.26
2)	0.20	3834	286.77	1164.00	27.38	0.940	1.2053	49.98
3)	0.30	3874	482.08	1172.58	27.47	0.901	1.2082	50.60
	L.D. G/CM <sup>3</sup>	TEMP K	PRESSURE PSIA	IMPETUS FT-LB/LB	MOL WT	CO-VOL IN <sup>3</sup> /LB	I.B. GAMMA	CP CAL/MOL
1)	0.10	3762	18475.7	384467.4	27.22	27.087	1.2051	11.773
2)	0.20	3834	41593.0	389483.9	27.38	26.029	1.2053	11.945
3)	0.30	3874	69920.1	392354.1	27.47	24.929	1.2082	12.093

## \*\*\* PROPELLANT M9 \*\*\*

PREDICTED COMBUSTION PRODUCTS  
 CONSTITUENT CONCENTRATIONS - MOLES PER KG OF PROPELLANT

NAME		1)	2)	3)
CO	GAS	10.3260	10.1947	10.1322
H2O	GAS	10.1395	10.3147	10.4262
CO2	GAS	7.80365	7.93093	7.99176
N2	GAS	5.35005	5.36677	5.37834
H2	GAS	1.61857	1.53767	1.48092
NO	GAS	$2.17715 \times 10^{-1}$	$1.81926 \times 10^{-1}$	$1.57876 \times 10^{-1}$
O2	GAS	$1.42826 \times 10^{-1}$	$8.76896 \times 10^{-2}$	$6.08297 \times 10^{-2}$
KOH	GAS	$6.82218 \times 10^{-2}$	$8.52989 \times 10^{-2}$	$9.59056 \times 10^{-2}$
NH3	GAS	$7.89408 \times 10^{-4}$	$1.75203 \times 10^{-3}$	$2.98886 \times 10^{-3}$
HCN	GAS	$3.20871 \times 10^{-4}$	$7.45747 \times 10^{-4}$	$1.33153 \times 10^{-3}$
CH4	GAS	$4.91291 \times 10^{-7}$	$2.01870 \times 10^{-6}$	$5.12559 \times 10^{-6}$
K	GAS	$7.76529 \times 10^{-2}$	$6.05716 \times 10^{-2}$	$5.00475 \times 10^{-2}$
HNO	GAS	$8.44639 \times 10^{-4}$	$1.10626 \times 10^{-3}$	$1.30364 \times 10^{-3}$
OH	GAS	$7.16651 \times 10^{-1}$	$5.65000 \times 10^{-1}$	$4.72361 \times 10^{-1}$
KO	GAS	$1.49824 \times 10^{-3}$	$1.49422 \times 10^{-3}$	$1.42523 \times 10^{-3}$
CH3	GAS	$1.42715 \times 10^{-6}$	$4.75613 \times 10^{-6}$	$1.06425 \times 10^{-5}$
H	GAS	$2.16391 \times 10^{-1}$	$1.55105 \times 10^{-1}$	$1.22055 \times 10^{-1}$
O	GAS	$5.67046 \times 10^{-2}$	$3.40918 \times 10^{-2}$	$2.35882 \times 10^{-2}$
CHO	GAS	$3.58516 \times 10^{-3}$	$6.18020 \times 10^{-3}$	$8.94861 \times 10^{-3}$
CN	GAS	$1.03556 \times 10^{-5}$	$1.96205 \times 10^{-5}$	$3.03971 \times 10^{-5}$
C(S)	SOLID	0.0	0.0	0.0
TOTAL GAS (MOLES/KG)		36.7410	36.5258	36.4081
DELTA Q (J/G)		-4410.0	-4516.5	-4576.5



## \*\*\* PROPELLANT M30 \*\*\*

## INGREDIENT AND FORMULATION INFORMATION

NAME	WT %	MOLE %	$\Delta H$ (CAL/MOL)	EMPIRICAL FORMULA
NC3	27.900	0.018	$-0.1692 \times 10^9$	C H O N 6000 7549 9901 2451
NG	22.420	17.162	$-0.8860 \times 10^5$	C H O N 3 5 9 3
NQ	47.540	79.410	$-0.2210 \times 10^5$	CH O N 4 2 4
EC	1.490	0.965	$-0.2510 \times 10^5$	C H ON 17 20 2
CRY	0.300	0.248	$-0.7890 \times 10^6$	Na AlF 3 6
C	0.100	1.449	0.0	C
AC	0.250	0.748	$-0.5927 \times 10^5$	C H O 3 6

ENERGY OF FORMATION: -1577.0 JOULES/GRAM

## ELEMENTAL COMPOSITION (MOLE %)

C	14.921
H	32.504
O	28.431
N	24.000
Na	0.043
Al	0.014
F	0.086

## \* \* SUMMARY OF PROPELLANT GAS THERMODYNAMIC PROPERTIES \* \*

	L.D. G/CM <sup>3</sup>	TEMP K	PRESSURE MPA	IMPETUS J/G	MOL WT	CO-VOL CM <sup>3</sup> /G	I.B. GAMMA	CP J/MOL
1)	0.10	2972	119.39	1062.88	23.23	1.096	1.2357	44.04
2)	0.20	2975	269.07	1062.30	23.25	1.051	1.2389	44.45
3)	0.30	2979	455.79	1062.56	23.27	1.002	1.2448	44.98
	L.D. G/CM <sup>3</sup>	TEMP K	PRESSURE PSIA	IMPETUS FT-LB/LB	MOL WT	CO-VOL IN <sup>3</sup> /LB	I.B. GAMMA	CP CAL/MOL
1)	0.10	2972	17315.7	355654.7	23.23	30.325	1.2357	10.526
2)	0.20	2975	39024.9	355454.5	23.25	29.099	1.2389	10.624
3)	0.30	2979	66106.9	355540.8	23.27	27.727	1.2448	10.750

## \*\*\* PROPELLANT M30 \*\*\*

PREDICTED COMBUSTION PRODUCTS  
 CONSTITUENT CONCENTRATIONS - MOLES PER KG OF PROPELLANT

NAME		1)	2)	3)
N2	GAS	11.9187	11.9103	11.8970
CO	GAS	11.8320	11.8765	11.9058
H2O	GAS	10.3636	10.4174	10.4680
H2	GAS	5.67263	5.60255	5.52086
CO2	GAS	2.99455	2.94389	2.90504
HF	GAS	$7.78531 \times 10^{-2}$	$7.77528 \times 10^{-2}$	$7.76547 \times 10^{-2}$
Na	GAS	$2.53142 \times 10^{-2}$	$7.52523 \times 10^{-3}$	$3.51884 \times 10^{-3}$
NH3	GAS	$9.81482 \times 10^{-3}$	$2.42809 \times 10^{-2}$	$4.49355 \times 10^{-2}$
AlOF	GAS	$6.81079 \times 10^{-3}$	$6.89676 \times 10^{-3}$	$6.98237 \times 10^{-3}$
AlOH	GAS	$6.36366 \times 10^{-3}$	$6.27380 \times 10^{-3}$	$6.17905 \times 10^{-3}$
NO	GAS	$5.75785 \times 10^{-3}$	$3.74178 \times 10^{-3}$	$2.83059 \times 10^{-3}$
HCN	GAS	$2.84941 \times 10^{-3}$	$7.46676 \times 10^{-3}$	$1.46701 \times 10^{-2}$
AlF	GAS	$1.06942 \times 10^{-3}$	$1.08626 \times 10^{-3}$	$1.10166 \times 10^{-3}$
O2	GAS	$1.96711 \times 10^{-4}$	$7.96710 \times 10^{-5}$	$4.34953 \times 10^{-5}$
NaO	GAS	$1.91616 \times 10^{-4}$	$5.75369 \times 10^{-5}$	$2.73148 \times 10^{-5}$
CH4	GAS	$9.70428 \times 10^{-5}$	$5.31608 \times 10^{-4}$	$1.62579 \times 10^{-3}$
Al	GAS	$3.64587 \times 10^{-5}$	$2.36759 \times 10^{-5}$	$1.77655 \times 10^{-5}$
A2O2	GAS	$4.71143 \times 10^{-6}$	$4.70251 \times 10^{-6}$	$4.69263 \times 10^{-6}$
HNO	GAS	$3.56068 \times 10^{-5}$	$3.71621 \times 10^{-5}$	$3.90546 \times 10^{-5}$
OH	GAS	$3.70423 \times 10^{-2}$	$2.37960 \times 10^{-2}$	$1.77355 \times 10^{-2}$
CH3	GAS	$2.61285 \times 10^{-5}$	$1.01455 \times 10^{-4}$	$2.54839 \times 10^{-4}$
H	GAS	$6.35521 \times 10^{-2}$	$4.06949 \times 10^{-2}$	$3.01386 \times 10^{-2}$
O	GAS	$2.64436 \times 10^{-4}$	$1.11809 \times 10^{-4}$	$6.35670 \times 10^{-5}$
CHO	GAS	$1.88302 \times 10^{-3}$	$3.13286 \times 10^{-3}$	$4.52459 \times 10^{-3}$
CN	GAS	$4.41584 \times 10^{-6}$	$7.80643 \times 10^{-6}$	$1.20013 \times 10^{-5}$
AlO2	GAS	0.0	0.0	0.0
F	GAS	$5.34058 \times 10^{-6}$	$3.54830 \times 10^{-6}$	$2.73672 \times 10^{-6}$
C(S)	SOLID	0.0	0.0	0.0
Na2S	SOLID	$1.73633 \times 10^{-2}$	$3.52863 \times 10^{-2}$	$3.93230 \times 10^{-2}$
Na2S	LIQUID	0.0	0.0	0.0
TOTAL GAS (MOLES/KG)		43.0207	42.9541	42.9091
DELTA Q (J/G)		-3379.0	-3383.4	-3387.3

## \*\*\* PROPELLANT M30A1 \*\*\*

## INGREDIENT AND FORMULATION INFORMATION

NAME	WT %	MOLE %	$\Delta H$ (CAL/MOL)	EMPIRICAL FORMULA
NC3	27.900	0.018	$-0.1692 \times 10^9$	C H O N 6000 7549 9901 2451
NG	22.420	17.235	$-0.8860 \times 10^5$	C H O N 3 5 9 3
NQ	46.840	78.570	$-0.2210 \times 10^5$	CH O N 4 2 4
EC	1.490	0.969	$-0.2510 \times 10^5$	C H ON 17 20 2
KS	1.000	1.002	$-0.3427 \times 10^6$	K SO 2 4
C	0.100	1.455	0.0	C
AC	0.250	0.751	$-0.5927 \times 10^5$	C H O 3 6

ENERGY OF FORMATION: -1605.9 JOULES/GRAM

## ELEMENTAL COMPOSITION (MOLE %)

C	14.925
H	32.390
O	28.666
N	23.844
K	0.116
S	0.058

## \* \* SUMMARY OF PROPELLANT GAS THERMODYNAMIC PROPERTIES \* \*

	L.D. G/CM <sup>3</sup>	TEMP K	PRESSURE MPA	IMPETUS J/G	MOL WT	CO-VOL CM <sup>3</sup> /G	I.B. GAMMA	CP J/MOL
1)	0.10	2971	118.49	1055.88	23.39	1.088	1.2350	44.16
2)	0.20	2980	267.43	1057.82	23.42	1.044	1.2380	44.59
3)	0.30	2986	452.85	1058.79	23.45	0.995	1.2437	45.12
	L.D. G/CM <sup>3</sup>	TEMP K	PRESSURE PSIA	IMPETUS FT-LB/LB	MOL WT	CO-VOL IN <sup>3</sup> /LB	I.B. GAMMA	CP CAL/MOL
1)	0.10	2971	17186.1	353308.4	23.39	30.106	1.2350	10.554
2)	0.20	2980	38787.3	353954.9	23.42	28.893	1.2380	10.657
3)	0.30	2986	65680.4	354277.8	23.45	27.539	1.2437	10.783

## \*\*\* PROPELLANT M30A1 \*\*\*

PREDICTED COMBUSTION PRODUCTS  
CONSTITUENT CONCENTRATIONS - MOLES PER KG OF PROPELLANT

NAME		1)	2)	3)
N2	GAS	11.7844	11.7763	11.7644
CO	GAS	11.6743	11.7111	11.7377
H2O	GAS	10.4318	10.4962	1.05476
H2	GAS	5.49291	5.41699	5.33670
CO2	GAS	3.07218	3.02170	2.98056
KOH	GAS	$3.24347 \times 10^{-2}$	$4.33352 \times 10^{-2}$	$5.12904 \times 10^{-2}$
COS	GAS	$1.30778 \times 10^{-2}$	$2.05905 \times 10^{-2}$	$2.68051 \times 10^{-2}$
NH3	GAS	$9.28949 \times 10^{-3}$	$2.28366 \times 10^{-2}$	$4.21479 \times 10^{-2}$
NO	GAS	$5.93816 \times 10^{-3}$	$3.97736 \times 10^{-3}$	$3.03826 \times 10^{-3}$
HCN	GAS	$2.64162 \times 10^{-3}$	$6.89554 \times 10^{-3}$	$1.35203 \times 10^{-2}$
O2	GAS	$2.11968 \times 10^{-4}$	$8.99100 \times 10^{-5}$	$4.98294 \times 10^{-5}$
CH4	GAS	$8.63066 \times 10^{-5}$	$4.62241 \times 10^{-4}$	$1.40223 \times 10^{-3}$
K	GAS	$8.23066 \times 10^{-2}$	$7.14074 \times 10^{-2}$	$6.34609 \times 10^{-2}$
HNO	GAS	$3.60970 \times 10^{-5}$	$3.88215 \times 10^{-5}$	$4.11761 \times 10^{-5}$
S	GAS	$1.89777 \times 10^{-3}$	$1.18963 \times 10^{-3}$	$8.10973 \times 10^{-4}$
OH	GAS	$3.78232 \times 10^{-2}$	$2.49169 \times 10^{-2}$	$1.87248 \times 10^{-2}$
KO	GAS	$3.38690 \times 10^{-5}$	$3.06279 \times 10^{-5}$	$2.79968 \times 10^{-5}$
SO	GAS	$1.34906 \times 10^{-2}$	$8.45937 \times 10^{-3}$	$5.77628 \times 10^{-3}$
HS	GAS	$2.52874 \times 10^{-2}$	$2.38760 \times 10^{-2}$	$2.13382 \times 10^{-2}$
CH3	GAS	$2.35735 \times 10^{-5}$	$9.11039 \times 10^{-5}$	$2.28300 \times 10^{-4}$
H	GAS	$6.24644 \times 10^{-2}$	$4.07123 \times 10^{-2}$	$3.03411 \times 10^{-2}$
O	GAS	$2.74055 \times 10^{-4}$	$1.21032 \times 10^{-4}$	$6.98134 \times 10^{-5}$
CHO	GAS	$1.82371 \times 10^{-3}$	$3.06765 \times 10^{-3}$	$4.44287 \times 10^{-3}$
KSO4	GAS	$3.34712 \times 10^{-9}$	$8.95806 \times 10^{-9}$	$1.56059 \times 10^{-8}$
CN	GAS	$4.15129 \times 10^{-6}$	$7.49004 \times 10^{-6}$	$1.15839 \times 10^{-5}$
S2	GAS	$1.81628 \times 10^{-3}$	$1.63508 \times 10^{-3}$	$1.32920 \times 10^{-3}$
SO3	GAS	$1.42810 \times 10^{-6}$	$9.14436 \times 10^{-7}$	$6.34703 \times 10^{-7}$
C(S)	SOLID	0.0	0.0	0.0
KSO\$	SOLID	0.0	0.0	0.0
KSO\$	LIQUID	0.0	0.0	0.0
TOTAL GAS (MOLES/KG)		42.7466	42.6960	42.6518
DELTA Q (J/G)		-3400.8	-3406.7	-3409.4

## \*\*\* PROPELLANT M30A2 \*\*\*

## INGREDIENT AND FORMULATION INFORMATION

NAME	WT %	MOLE %	$\Delta H$ (CAL/MOL)	EMPIRICAL FORMULA
NC	26.910	0.017	$-0.1692 \times 10^9$	C H O N 6000 7549 9901 2451
NG	22.420	16.819	$-0.8860 \times 10^5$	C H O N 3 5 9 3
NQ	46.090	75.448	$-0.2210 \times 10^5$	CH O N 4 2 4
EC	1.490	0.946	$-0.2510 \times 10^5$	C H ON 17 20 2
KN	2.740	4.617	$-0.1178 \times 10^6$	KNO 3
C	0.100	1.420	0.0	C
AC	0.250	0.733	$-0.5927 \times 10^5$	C H O 3 6

ENERGY OF FORMATION: -1624.7 JOULES/GRAM

## ELEMENTAL COMPOSITION (MOLE %)

C	14.749
H	32.075
O	28.975
N	23.926
K	0.276

## \* \* SUMMARY OF PROPELLANT GAS THERMODYNAMIC PROPERTIES \* \*

	L.D. G/CM <sup>3</sup>	TEMP K	PRESSURE MPA	IMPETUS J/G	MOL WT	CO-VOL CM <sup>3</sup> /G	I.B. GAMMA	CP J/MOL
1)	0.10	3015	118.65	1058.65	23.68	1.076	1.2329	44.47
2)	0.20	3024	267.38	1060.36	23.71	1.034	1.2358	44.90
3)	0.30	3029	452.12	1061.14	23.73	0.986	1.2414	45.41
	L.D. G/CM <sup>3</sup>	TEMP K	PRESSURE PSIA	IMPETUS FT-LB/LB	MOL WT	CO-VOL IN <sup>3</sup> /LB	I.B. GAMMA	CP CAL/MOL
1)	0.10	3015	17209.4	354234.8	23.68	29.793	1.2329	10.629
2)	0.20	3024	38780.3	354804.5	23.71	28.610	1.2358	10.731
3)	0.30	3029	65573.8	355065.7	23.73	27.289	1.2414	10.854

\*\*\* PROPELLANT M30A2 \*\*\*

PREDICTED COMBUSTION PRODUCTS  
CONSTITUENT CONCENTRATIONS - MOLES PER KG OF PROPELLANT

NAME		1)	2)	3)
N2	GAS	11.7309	11.7246	11.7148
CO	GAS	11.2327	11.2819	1.13190
H2O	GAS	10.5892	10.6408	10.6822
H2	GAS	5.03710	4.97207	4.90181
CO2	GAS	3.23687	3.18264	3.13857
KOH	GAS	$8.06273 \times 10^{-2}$	$1.06827 \times 10^{-1}$	$1.25691 \times 10^{-1}$
NH3	GAS	$7.98141 \times 10^{-3}$	$1.95943 \times 10^{-2}$	$3.61029 \times 10^{-2}$
NO	GAS	$7.97847 \times 10^{-3}$	$5.32518 \times 10^{-3}$	$4.05526 \times 10^{-3}$
HCN	GAS	$2.22006 \times 10^{-3}$	$5.79408 \times 10^{-3}$	$1.13470 \times 10^{-2}$
O2	GAS	$3.46387 \times 10^{-4}$	$1.46155 \times 10^{-4}$	$8.06511 \times 10^{-5}$
CH4	GAS	$5.68765 \times 10^{-5}$	$3.05282 \times 10^{-4}$	$9.26857 \times 10^{-4}$
K	GAS	$1.90275 \times 10^{-1}$	$1.64086 \times 10^{-1}$	$1.45245 \times 10^{-1}$
HNO	GAS	$4.68994 \times 10^{-5}$	$5.01942 \times 10^{-5}$	$5.29986 \times 10^{-5}$
OH	GAS	$4.72786 \times 10^{-2}$	$3.10605 \times 10^{-2}$	$2.32856 \times 10^{-2}$
KO	GAS	$1.04237 \times 10^{-4}$	$9.32706 \times 10^{-5}$	$8.45732 \times 10^{-5}$
CH3	GAS	$1.83503 \times 10^{-5}$	$7.09000 \times 10^{-5}$	$1.77406 \times 10^{-4}$
H	GAS	$6.80708 \times 10^{-2}$	$4.43398 \times 10^{-2}$	$3.30191 \times 10^{-2}$
O	GAS	$4.04933 \times 10^{-4}$	$1.78085 \times 10^{-4}$	$1.02336 \times 10^{-4}$
CHO	GAS	$1.85003 \times 10^{-3}$	$3.10582 \times 10^{-3}$	$4.48701 \times 10^{-3}$
CN	GAS	$4.30934 \times 10^{-6}$	$7.75456 \times 10^{-6}$	$1.19499 \times 10^{-5}$
C(S)	SOLID	0.0	0.0	0.0
TOTAL GAS (MOLES/KG)		42.2341	42.1830	42.1410
DELTA Q (J/G)		-3434.1	-3437.4	-3437.8

## \*\*\* TRIAMINOGUANIDINE/HMX PROPELLANT RGP-150 \*\*\*

## INGREDIENT AND FORMULATION INFORMATION

NAME	WT %	MOLE %	$\Delta H$ (CAL/MOL)	EMPIRICAL FORMULA
NC3	20.000	0.019	$-0.1692 \times 10^9$	C H O N 6000 7549 9901 2451
TAGN	45.000	69.771	$-0.1140 \times 10^5$	CH O N 9 3 7
HMX	29.500	25.811	$0.1792 \times 10^5$	C H O N 4 8 8 8
DOP	4.800	3.185	$-0.2570 \times 10^6$	C H O 24 38 4
RES	0.200	0.471	$-0.8630 \times 10^5$	C H O 6 6 2
KS	0.500	0.744	$-0.3427 \times 10^6$	K SO 2 4

ENERGY OF FORMATION: -753.2 JOULES/GRAM

## ELEMENTAL COMPOSITION (MOLE %)

C	12.935
H	38.896
O	21.915
N	26.175
K	0.052
S	0.026

## \* \* SUMMARY OF PROPELLANT GAS THERMODYNAMIC PROPERTIES \* \*

	L.D. G/CM <sup>3</sup>	TEMP K	PRESSURE MPA	IMPETUS J/G	MOL WT	CO-VOL CM <sup>3</sup> /G	I.B. GAMMA	CP J/MOL
1)	0.10	2688	126.46	1111.18	20.11	1.212	1.2562	41.07
2)	0.20	2694	288.91	1110.72	20.16	1.155	1.2590	41.60
3)	0.30	2701	494.90	1109.22	20.24	1.092	1.2651	42.33
	L.D. G/CM <sup>3</sup>	TEMP K	PRESSURE PSIA	IMPETUS FT-LB/LB	MOL WT	CO-VOL IN <sup>3</sup> /LB	I.B. GAMMA	CP CAL/MOL
1)	0.10	2688	18341.3	371813.6	20.11	33.535	1.2562	9.816
2)	0.20	2694	41902.5	371656.7	20.16	31.965	1.2590	9.942
3)	0.30	2701	71779.4	371154.8	20.24	30.217	1.2651	10.118

## \*\*\* TRIAMINO GUANIDINE/HMX PROPELLANT RGP-150 \*\*\*

PREDICTED COMBUSTION PRODUCTS  
CONSTITUENT CONCENTRATIONS - MOLES PER KG OF PROPELLANT

NAME		1)	2)	3)
N2	GAS	14.2804	14.2379	14.1747
CO	GAS	12.8129	12.8012	12.7424
H2	GAS	12.6339	12.4390	12.1291
H2O	GAS	8.51736	8.58274	8.66677
CO2	GAS	1.29909	1.26945	1.25380
NH3	GAS	$4.18799 \times 10^{-2}$	$1.06165 \times 10^{-1}$	$1.98875 \times 10^{-1}$
HCN	GAS	$1.27741 \times 10^{-2}$	$3.43672 \times 10^{-2}$	$6.82378 \times 10^{-2}$
COS	GAS	$1.08446 \times 10^{-2}$	$1.49234 \times 10^{-2}$	$1.78166 \times 10^{-2}$
KOH	GAS	$9.28925 \times 10^{-3}$	$1.32539 \times 10^{-2}$	$1.66016 \times 10^{-2}$
CH4	GAS	$3.09260 \times 10^{-3}$	$1.73116 \times 10^{-2}$	$5.24515 \times 10^{-2}$
NO	GAS	$5.57195 \times 10^{-4}$	$3.64578 \times 10^{-4}$	$2.82180 \times 10^{-4}$
O2	GAS	$3.27029 \times 10^{-6}$	$1.32510 \times 10^{-6}$	$7.44746 \times 10^{-7}$
K	GAS	$4.80959 \times 10^{-2}$	$4.41331 \times 10^{-2}$	$4.07857 \times 10^{-2}$
HNO	GAS	$4.83495 \times 10^{-6}$	$5.16946 \times 10^{-6}$	$5.63089 \times 10^{-6}$
S	GAS	$4.25834 \times 10^{-4}$	$2.24584 \times 10^{-4}$	$1.38586 \times 10^{-4}$
OH	GAS	$6.12214 \times 10^{-3}$	$3.94546 \times 10^{-3}$	$2.98386 \times 10^{-3}$
KO	GAS	$1.84789 \times 10^{-6}$	$1.75190 \times 10^{-6}$	$1.70750 \times 10^{-6}$
SO	GAS	$1.19625 \times 10^{-3}$	$6.31083 \times 10^{-4}$	$3.93654 \times 10^{-4}$
HS	GAS	$1.51082 \times 10^{-2}$	$1.21763 \times 10^{-2}$	$9.85156 \times 10^{-3}$
CH3	GAS	$2.26659 \times 10^{-4}$	$9.10411 \times 10^{-4}$	$2.31033 \times 10^{-3}$
H	GAS	$3.68665 \times 10^{-2}$	$2.35574 \times 10^{-2}$	$1.74356 \times 10^{-2}$
O	GAS	$1.18557 \times 10^{-5}$	$5.03809 \times 10^{-6}$	$2.93521 \times 10^{-6}$
CHO	GAS	$1.53057 \times 10^{-3}$	$2.60730 \times 10^{-3}$	$3.84016 \times 10^{-3}$
KSO4	GAS	$1.62935 \times 10^{-11}$	$4.33725 \times 10^{-11}$	$7.95394 \times 10^{-11}$
CN	GAS	$3.90147 \times 10^{-6}$	$7.15650 \times 10^{-6}$	$1.13363 \times 10^{-5}$
S2	GAS	$5.59295 \times 10^{-4}$	$3.69511 \times 10^{-4}$	$2.47039 \times 10^{-4}$
SO3	GAS	$9.73966 \times 10^{-9}$	$5.22310 \times 10^{-9}$	$3.39891 \times 10^{-9}$
C(S)	SOLID	0.0	0.0	0.0
KSO\$	SOLID	0.0	0.0	0.0
KSO\$	LIQUID	0.0	0.0	0.0
TOTAL GAS (MOLES/KG)		49.7322	49.6053	49.3990
DELTA Q (J/G)		-3227.7	-3237.5	-3253.3



## \*\*\* TRIAMINO GUANIDINE/RDX PROPELLANT RGP-150 \*\*\*

## INGREDIENT AND FORMULATION INFORMATION

NAME	WT %	MOLE %	$\Delta H$ (CAL/MOL)	EMPIRICAL FORMULA
NC3	20.000	0.018	$-0.1692 \times 10^9$	C H O N 6000 7549 9901 2451
TAGN	45.000	64.243	$-0.1140 \times 10^5$	CH O N 9 3 7
RDX	29.500	31.689	$0.1469 \times 10^5$	C H N O 3 6 6 6
DOP	4.800	2.932	$-0.2570 \times 10^6$	C H O 24 38 4
RES	0.200	0.433	$-0.8630 \times 10^5$	C H O 6 6 2
KS	0.500	0.685	$-0.3427 \times 10^6$	K SO 2 4

ENERGY OF FORMATION: -746.3 JOULES/GRAM

## ELEMENTAL COMPOSITION (MOLE %)

C	12.935
H	38.896
O	21.915
N	26.175
K	0.052
S	0.026

## \* \* SUMMARY OF PROPELLANT GAS THERMODYNAMIC PROPERTIES \* \*

	L.D. G/CM <sup>3</sup>	TEMP K	PRESSURE MPA	IMPETUS J/G	MOL WT	CO-VOL CM <sup>3</sup> /G	I.B. GAMMA	CP J/MOL
1)	0.10	2692	126.65	1112.90	20.11	1.212	1.2561	41.08
2)	0.20	2698	289.36	1112.44	20.16	1.155	1.2589	41.60
3)	0.30	2705	495.67	1110.92	20.24	1.092	1.2650	42.34
	L.D. G/CM <sup>3</sup>	TEMP K	PRESSURE PSIA	IMPETUS FT-LB/LB	MOL WT	CO-VOL IN <sup>3</sup> /LB	I.B. GAMMA	CP CAL/MOL
1)	0.10	2692	18369.8	372389.9	20.11	33.536	1.2561	9.819
2)	0.20	2698	41967.5	372231.1	20.16	31.965	1.2589	9.943
3)	0.30	2705	71890.3	371724.0	20.24	30.218	1.2650	10.119

## \*\*\* TRIAMINO GUANIDINE/RDX PROPELLANT RGP-150 \*\*\*

PREDICTED COMBUSTION PRODUCTS  
CONSTITUENT CONCENTRATIONS - MOLES PER KG OF PROPELLANT

NAME		1)	2)	3)
N2	GAS	14.2804	14.2380	14.1749
CO	GAS	12.8143	12.8028	12.7444
H2	GAS	12.6326	12.4385	12.1300
H2O	GAS	8.51856	8.58381	8.66754
CO2	GAS	1.29771	1.26809	1.25240
NH3	GAS	$4.17765 \times 10^{-2}$	$1.05901 \times 10^{-1}$	$1.98405 \times 10^{-1}$
HCN	GAS	$1.27890 \times 10^{-2}$	$3.44048 \times 10^{-2}$	$6.83159 \times 10^{-2}$
COS	GAS	$1.07752 \times 10^{-2}$	$1.48507 \times 10^{-2}$	$1.77496 \times 10^{-2}$
KOH	GAS	$9.30414 \times 10^{-3}$	$1.32739 \times 10^{-2}$	$1.66246 \times 10^{-2}$
CH4	GAS	$3.05392 \times 10^{-3}$	$1.70982 \times 10^{-2}$	$5.18343 \times 10^{-2}$
NO	GAS	$5.70220 \times 10^{-4}$	$3.73033 \times 10^{-4}$	$2.88564 \times 10^{-4}$
O2	GAS	$3.38332 \times 10^{-6}$	$1.37055 \times 10^{-6}$	$7.69633 \times 10^{-7}$
K	GAS	$4.80810 \times 10^{-2}$	$4.41131 \times 10^{-2}$	$4.07627 \times 10^{-2}$
HNO	GAS	$4.95379 \times 10^{-6}$	$5.29565 \times 10^{-6}$	$5.76534 \times 10^{-6}$
S	GAS	$4.31218 \times 10^{-4}$	$2.27731 \times 10^{-4}$	$1.40618 \times 10^{-4}$
OH	GAS	$6.24227 \times 10^{-3}$	$4.02240 \times 10^{-3}$	$3.04077 \times 10^{-3}$
KO	GAS	$1.88809 \times 10^{-6}$	$1.78944 \times 10^{-6}$	$1.74299 \times 10^{-6}$
SO	GAS	$1.20967 \times 10^{-3}$	$6.39059 \times 10^{-4}$	$3.98884 \times 10^{-4}$
HS	GAS	$1.51630 \times 10^{-2}$	$1.22384 \times 10^{-2}$	$9.91066 \times 10^{-3}$
CH3	GAS	$2.27122 \times 10^{-4}$	$9.12298 \times 10^{-4}$	$2.31559 \times 10^{-3}$
H	GAS	$3.74211 \times 10^{-2}$	$2.39091 \times 10^{-2}$	$1.76909 \times 10^{-2}$
O	GAS	$1.22639 \times 10^{-5}$	$5.21008 \times 10^{-6}$	$3.03298 \times 10^{-6}$
CHO	GAS	$1.54808 \times 10^{-3}$	$2.63693 \times 10^{-3}$	$3.88317 \times 10^{-3}$
KSO4	GAS	$1.61552 \times 10^{-11}$	$4.30658 \times 10^{-11}$	$7.90377 \times 10^{-11}$
CN	GAS	$3.98387 \times 10^{-6}$	$7.30595 \times 10^{-6}$	$1.15685 \times 10^{-5}$
S2	GAS	$5.57259 \times 10^{-4}$	$3.69264 \times 10^{-4}$	$2.47352 \times 10^{-4}$
SO3	GAS	$9.93339 \times 10^{-9}$	$5.33448 \times 10^{-9}$	$3.47271 \times 10^{-9}$
C(S)	SOLID	0.0	0.0	0.0
KSO\$	SOLID	0.0	0.0	0.0
KSO\$	LIQUID	0.0	0.0	0.0
TOTAL GAS (MOLES/KG)		49.7327	49.6062	49.4008
DELTA Q (J/G)		-3234.4	-3244.3	-3260.0

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# APPENDIX IV TYPICAL BLAKE OUTPUT

\*\*\* PROPELLANT AR2206 \*\*\*

THE COMPOSITION IS

NAME	PCT WT	PCT MOLE	DEL H-CAL/M	FORMULA
NCS	89.810	0.269	-0.1646D+09	C 6090 H 7364 O 10271 N 2636
DP	0.980	4.866	0.3107D+05	C 12 H 1 N 11
KS	0.390	1.880	-0.3427D+06	K 2 S 1 O 4
KN	0.500	4.155	-0.1178D+06	K 1 N 1 O 3
C	0.100	7.002	0.0	C 1
DN	7.040	12.476	-0.1710D+05	C 7 H 6 O 4 N 2
H2O	0.980	45.705	-0.6832D+05	H 2 O 1
AL	0.200	3.648	-0.6642D+05	C 2 H 6 O 1

THE ENERGY OF FORMATION IS -2448.0 JOULES/GRAM

COMPONENTS CO H2O N2 H2 COS KON

THE ELEMENTS AND PERCENT BY MOLE

C	23.891
H	29.241
O	36.972
N	9.774
K	0.099
S	0.023

**THERE ARE 27 GASEOUS CONSTITUENTS SELECTED:**

	NAME	BKW CO-VOL	L-J EPS/K	L-J SIGMA	A1	A2	A3	A4	A5	A6	A7	A8	A9
1.	CO	390.0	91.7	3.690	6.11966	-0.54166	0.09643	-0.00635	-2.41493	0.83944	-0.10225	-31352.0	52.9746
2.	H2O	250.0	542.5	2.790	6.50348	0.93789	-0.22670	0.01844	-3.80398	1.83571	-0.30023	-61993.6	47.8706
3.	CO2	600.0	195.2	3.941	9.65814	-0.69946	0.12807	-0.00830	-3.27805	0.81665	-0.08553	-103112.7	59.8431
4.	N2	380.0	71.4	3.798	7.14487	-1.09877	0.22753	-0.00830	-3.27805	0.81665	-0.13783	-5952.9	50.9800
5.	H2	180.0	59.7	2.827	2.61071	1.13725	-0.22387	0.01792	-0.19546	0.37621	-0.08873	-597.7	37.5166
6.	COS	0.0	100.0	3.000	9.07572	-0.47894	0.09730	-0.00658	-2.27231	0.48548	-0.04719	-46117.2	66.5255
7.	NO	386.0	116.7	3.492	5.77838	-0.43892	0.08202	-0.00561	-1.79245	0.50897	-0.04564	16765.3	57.0969
8.	KOH	0.0	100.0	3.000	7.27052	0.40176	-0.10705	0.00896	-1.70167	0.87842	-0.16291	-59999.7	68.1294
9.	NH3	476.0	558.3	2.900	13.60829	-0.93312	0.18185	-0.00958	-9.06058	3.51672	-0.50840	-22985.7	45.5074
10.	HCN	359.0	344.7	3.339	9.48792	-0.37343	0.04424	-0.02222	-4.59416	1.73906	-0.25679	24383.5	53.6459
11.	CH4	528.0	148.6	3.758	20.35251	-1.95871	0.26284	-0.01397	-14.43248	5.11197	-0.67906	-38010.8	38.5449
12.	O2	350.0	106.7	3.467	3.85610	0.26367	0.02353	-0.00584	0.47043	0.53106	-0.11560	-3429.8	58.1987
13.	K	0.0	100.0	3.000	2.66250	2.08549	-0.89347	0.12928	-8.36971	12.54192	-5.77007	18534.0	32.8000
14.	HNO	0.0	100.0	3.000	9.34312	-0.70980	0.10910	-0.00667	-4.08659	1.26638	-0.15056	15255.4	58.7629
15.	S	0.0	100.0	3.000	1.83331	0.19365	0.01065	-0.00358	0.77619	-0.26477	0.03824	65713.8	47.5476
16.	OH	226.0	100.0	3.000	4.22400	0.47240	-0.11211	0.00942	-1.70189	0.97134	-0.16944	7437.0	49.0478
17.	KO	0.0	100.0	3.000	4.49837	0.11393	0.00019	-0.00002	0.00503	-0.02588	0.00186	14185.2	67.4039
18.	SO	0.0	100.0	3.000	1.92172	1.33801	-0.22714	0.01363	2.24044	-1.13902	0.18518	-219.7	63.6970
19.	HS	0.0	100.0	3.000	6.12907	-0.41325	0.06726	-0.00371	-2.95581	1.32671	-0.19604	30547.3	51.9361
20.	CH3	525.0	100.0	3.000	13.82287	-0.74765	0.05695	-0.00032	-9.14376	3.65133	-0.54025	23004.1	46.4265
21.	H	13.4	100.0	3.000	2.50004	0.00000	-0.00000	0.00000	0.00000	-0.00000	0.00000	50621.8	33.4031
22.	O	212.8	100.0	3.000	2.51350	-0.22300	0.05179	-0.00323	-0.36806	0.16997	-0.02504	57813.5	44.4218
23.	CHO	700.0	100.0	3.000	10.04357	-1.09647	0.20969	-0.01680	-4.57561	1.36019	-0.16753	955.9	59.4686
24.	KS04	0.0	100.0	3.000	18.33685	-0.14520	0.02868	-0.00211	-0.33516	-0.85697	0.15831	-276800.0	127.6058
25.	CN	0.0	100.0	3.000	2.71179	0.54169	0.09568	-0.02040	1.50282	-0.10183	0.20537	101465.0	58.3631
26.	S2	0.0	100.0	3.000	4.48800	0.03544	-0.00050	0.00003	0.02430	-0.11854	0.01769	27643.9	64.5607
27.	SO3	0.0	100.0	3.000	10.99345	-0.39070	0.07318	-0.00521	-1.21408	-0.44194	0.12072	-105586.0	77.9915

THE FLOOR IS AT 12

THERE ARE 2 CONDENSED CONSTITUENTS SELECTED

N A M E		THERMO CONSTS (LIQUID FIRST, THEN SOLID) FOLLOWED BY CONDENSED EQN OF STATE CONSTS (LIQUID FIRST, THEN SOLID)								
(FRMS IN LIB PRT)		B1/C1	B2/C2	B3/C3	B4/C4	B5/C5	B6/C6	B7/C7	B8/C8	B9/C9
1.	C(S)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		0.01949D+00	-4.08033D-01	8.28917D-02	-4.97439D-03	-1.05594D+00	-8.19033D-02	4.56811D-02	-4.91945D+03	4.45242D+00
		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		4.99259D+00	3.96280D-05	1.19136D-09	-6.37752D-06	1.19250D-10	-3.75578D-15	3.58287D-12	-1.00976D-16	0.0
2.	KSO\$	2.37926D+01	3.23229D-11	-6.91624D-12	5.46303D-13	7.19842D-11	-3.36938D-11	5.67762D-12	-3.46651D+05	1.08603D+02
		1.34865D+01	1.01149D+01	-3.08663D-12	2.43570D-13	3.23135D-11	-1.51606D-11	2.55967D-12	-3.51544D+05	6.84044D+01
		7.48500D+01	1.75000D-02	4.10000D-06	9.59000D-10	0.0	0.0	0.0	0.0	0.0
		6.53700D+01	8.20000D-03	0.0	0.0	0.0	0.0	0.0	0.0	0.0

PROPELLANT THERMODYNAMIC PROPERTIES

LENNARD-JONES 6,12 EQUATION OF STATE

	P (ATM)	V (CC/G)	T (K)	H (CAL/G)	E (CAL/G)	S (CAL/G)	RHO (G/CC)	CV (CAL/G)	ADKIP	ALPHA	BETA
COMPONENTS	CO	N2O	N2	N2	N2	KOH	COS				
1)	1115.62	10.000	2924.	-314.90	-585.07	2.224	0.100	0.367	1.3740	4.381	3.916
COMPONENTS	CO	N2O	N2	N2	N2	KOH	COS				
2)	2513.50	5.000	2932.	-280.72	-585.07	2.160	0.200	0.361	1.5308	4.249	3.429
COMPONENTS	CO	N2O	N2	N2	N2	KOH	COS				
3)	4248.85	1.333	2936.	-242.09	-585.07	2.120	0.300	0.358	1.6891	4.100	3.019

CONSTITUENT CONCENTRATIONS - MOLES PER KG OF COMPOUND

NAME		1)	2)	3)
CO	GAS	1.87213D+01	1.87579D+01	1.87729D+01
N2O	GAS	8.38352D+00	8.44098D+00	8.48081D+00
N2	GAS	5.48011D+00	5.41480D+00	5.35135D+00
N2	GAS	4.65087D+00	4.64435D+00	4.63447D+00
CO2	GAS	4.02967D+00	3.98153D+00	3.95185D+00
KOH	GAS	2.23719D-02	3.04822D-02	3.65704D-02
COS	GAS	8.35682D-03	1.18319D-02	1.42474D-02
NH3	GAS	5.89923D-03	1.44689D-02	2.66357D-02
NO	GAS	2.42703D-03	1.60875D-03	1.21622D-03
HCN	GAS	3.23285D-03	8.43634D-03	1.66300D-02
O2	GAS	1.00927D-04	4.23697D-05	2.32726D-05
CH4	GAS	1.90151D-04	1.02756D-03	3.16679D-03
K	GAS	7.18272D-02	6.37180D-02	5.76331D-02
HNO	GAS	1.45252D-05	1.54394D-05	1.61975D-05
S	GAS	6.34397D-04	3.55022D-04	2.22029D-04
OH	GAS	2.54641D-02	1.66879D-02	1.24966D-02
KO	GAS	1.94373D-05	1.78168D-05	1.64543D-05
SO	GAS	3.69292D-03	2.06501D-03	1.28885D-03
HS	GAS	9.16671D-03	7.74628D-03	6.36106D-03
CH3	GAS	4.54125D-05	1.76169D-04	4.47001D-04
H	GAS	5.42758D-02	3.52979D-02	2.63335D-02
O	GAS	1.61564D-04	7.06757D-05	4.05243D-05
CHO	GAS	2.62082D-03	4.40875D-03	6.42909D-03
KSO4	GAS	4.35965D-10	1.08253D-09	1.75855D-09
CN	GAS	4.23740D-06	7.59976D-06	1.17820D-05
S2	GAS	2.65109D-04	1.91563D-04	1.31234D-04
SO3	GAS	2.35292D-07	1.33550D-07	8.39586D-08
C(S)	SOLID	0.0	0.0	0.0
KSO3	SOLID	0.0	0.0	0.0
KSO3	LIQUID	0.0	0.0	0.0
TOTAL GAS (MOLES/KG)		41.4762	41.4382	41.4013
DELTA Q (J/G)		-3221.5	-3225.5	-3228.0

\*\*\* PROPELLANT AR2206 \*\*\*

\* \* SUMMARY OF PROPELLANT GAS THERMODYNAMIC PROPERTIES \* \*

	RHO/L G/CC	TEMP K	PRESSURE MPA	IMPETUS J/G	MOL WT	CO-VOL CC/G	I. B. GAMMA	CP J/MOL	B(T) CC/MOL	C(T) (CC/MOL)**2
1)	0.1000	2924.	113.04	1008.33	24.11	1.078	1.2382	43.68	26.82	563.
2)	0.2000	2932.	254.68	1009.84	24.13	1.034	1.2414	44.10	26.81	563.
3)	0.3000	2936.	430.52	1010.61	24.15	0.986	1.2473	44.60	26.80	563.

RHO/L G/CC	TEMP K	PRESSURE PSIA	IMPETUS FT-LB/LB	MOL WT	CO-VOL IN**3/LB	I.B. GAMMA	CP CAL/MOLE	B(T) CC	C(T) CC**2
1) 0.1000	2924.	16395.0	337395.1	24.110	29.850	1.2382	10.441	26.81	563
2) 0.2000	2932.	36938.4	337900.9	24.132	28.627	1.2414	10.540	26.81	563
3) 0.3000	2936.	62441.1	338157.2	24.154	27.279	1.2473	10.660	26.80	563

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Principal Officer, Composite Propellants & Explosives Group	51
Dr P.J. Carson, Gun Propulsion Research Group	52
Mr K.H.J. Adams, Gun Propulsion Research Group	53
Mr R.H. Weldon, Gun Propulsion Research Group	54
Mr M.R. Grivell, Gun Propulsion Research Group	55
Mr I.R. Johnston, Gun Propulsion Research Group	56



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Mr D.R. Kirk, Nitrocellulose Propellants Group	62
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BLAKE computer program

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## 16 SUMMARY OR ABSTRACT:

(if this is security classified, the announcement of this report will be similarly classified)

The BLAKE computer program has been used to calculate certain quantities required for gun interior ballistic simulation and prediction. Thermodynamic data for gun propellants manufactured in Australia, and several which are candidates for local production, are tabulated for reference. A summary of the theoretical framework of the program is included.

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8